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*Chosen by the various Agricultural Associations of the state to advise with the Experiment Station as to the nature and scope of its work under state appropriations. *v*

(INTRODUCTORY NOTE.)

This report is for the special use of members of the General Assembly. It is made by binding together the bulletins of the Experiment Station that have been issued during the last two years as a result of investigations under state appropriations. Aside from this there remains a large amount of unpublished matter,—some of it awaiting further investigations, and much of it requiring simply to be prepared for press.

Investigations under these various funds have been more prolific of important results than the most sanguine friends of agriculture could have hoped, and in many respects the agriculture of the state is being profoundly altered and permanently improved as a result.

BULLETINS IN PRESS.

No. 98. "The Curculio of the Plum and the Apple." By Professor C. S. Crandall. A bulletin of eighty pages, three colored plates and many half tones. Giving result of two years investigation in damage from plum and apple curculio, together with recommendations for treatment.

No. 99. "Soil Treatment of Lower Illinois Glaciation." By C. G. Hopkins. Treatment of the general character and peculiarities of the southern Illinois soils from the black prairie lands to the Ozark ridge.

"Eight Generations of Corn Breeding." By L. H. Smith. Giving the full history of change in composition of Indian corn by selection, as a result of eight years of work, with records covering the entire experiment.

The following bulletins are in preparation and will shortly be published:

"Effect of Detasseling in Corn Breeding," Dr. C. G. Hopkins.

"A Comparison of the Methods of Feeding Corn and Clover for fattening Steers." By Professor H. W. Mumford.

"Dust Versus Liquid Spraying." Professor J. C. Blair and Professor C. S. Crandall.

"Bitter Rot." (Botanical Investigations.) Dr. T. J. Burrill.

"Bitter Rot." (Horticultural Investigations.) Professor J. C. Blair.

"Cold Storage of Apples." Professor J. C. Blair.

"Picking, Packing, and Marketing of Apples." Professor J. C. Blair and Professor C. S. Crandall.

"Spraying for the Codling Moth." Professor J. W. Lloyd.

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5. Bulletin No. 90, Fattening Steers of the Various Market Grades.
6. Bulletin No. 91, Preventing Contamination of Milk.
7. Bulletin No. 92, City Milk Supply.
8. Circular No. 73, Milk Production at the University of Illinois.
9. Bulletin No. 93, Soil Treatment for Peaty Swamp Lands, Including Reference to Sand and "Alkali" Soils.
10. Bulletin No. 94, Nitrogen Bacteria and Legumes.
11. Bulletin No. 96, The Testing of Corn for Seed.
12. Bulletin No. 97, Market Classes and Grades of Swine.
13. Circular No. 68, Methods of Maintaining the Productive Capacity of Illinois Soils.
14. Circular No. 74, Directions for the Breeding of Corn.
15. Circular No. 75, Feeding Dairy Cows.
16. Circular No. 78, Clean Milk.
17. Circular No. 79, Present Methods of Beef Production.
18. Circular No. 82, The Physical Improvement of Soils.
19. Circular No. 83, The Swine Industry from the Market Standpoint.

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Agricultural Experiment Station.

URBANA, JUNE, 1903.



BULLETIN No. 85.

RECORDS OF INDIVIDUAL COWS ON DAIRY FARMS.

BY ARTHUR J. GLOVER, B. AGR., CHIEF ASSISTANT IN DAIRY HUSBANDRY,
AGRICULTURAL EXPERIMENT STATION.

SUMMARY.

Eight herds are reported in this bulletin, containing 144 cows that have completed a year's work. The eight dairies had 176 cows at the beginning of the test, but 32 of them were sold before the end of the year.

Some of the herds returned their owners a good profit, others a small profit, and one herd was kept at a loss. Six herds out of the eight contained cows that did not pay for the feed they consumed.

In estimating the profit or loss on a cow it was counted that the calf paid for her keep while dry and the skim milk paid for labor.

The cow that yielded the most product gave 8,949 pounds of milk, and made 472 pounds of butter. The poorest cow produced 1,482 pounds of milk, 68 pounds of butter, and the average production for all the herds, except Gurler's (D), was 4,721 pounds of milk, 3.67 percent fat, 173 pounds of butter fat, and 202 pounds of butter.

It would not give the average production of the ordinary cows in Illinois if Gurler's herd were included, for he has been applying the scales and test for a number of years, hence his improved dairy. It should also be considered that the men who took up this work had been interested in improving their dairies, and undoubtedly have better cows than the average.

The most profitable cow gave a net profit of \$57.22 and the poorest cow was kept at an actual loss of \$17.83. The average net profit was \$9.96 per cow.

The above facts show clearly that the average production of the Illinois dairy cow can be doubled and the profit increased fourfold.

This can be done with little expense to the farmer. It will require better care and better feed for his stock, and the application of the scales and the Babcock test so that he can select and breed his animals more intelligently.

The results in this bulletin indicate that good care and good feed with judicious selection are the prime factors necessary for profitable milk and butter production.

For over a year the Department of Dairy Husbandry of the University of Illinois has been conducting field work among the dairymen of the state. A number of them were persuaded to weigh and sample each mess of milk a sufficient number of times during the year so that the performance of each cow could be estimated with a considerable degree of accuracy. It has been demonstrated by a number of our experiment stations that many cows are kept in the dairy at a very small profit and some at an actual loss. In order to determine the facts and to lead the dairymen to realize their full force and meaning a man was sent into the field to persuade a number of them to keep a record of every cow in their herds. While this bulletin gives no facts new to science, yet it presents a line of work on which we have but little data and it brings the farmers face to face with facts that exist upon their own farms. It shows them that some herds are kept at a good profit, some at a small profit, and others at an actual loss.

HOW THE FARM TEST WAS MADE.

The farmers who took up this work were required to weigh and sample the milk from each cow in the herd every seventh week for fourteen consecutive milkings. After each cow was milked the milk was poured into a weighing pail, weighed, and the weight recorded on a milk sheet directly under the cow's name. A small sample of milk was then taken with a sample dipper or a milk thief and put into the sample bottles. Corrosive sublimate tablets were used to preserve the samples of milk. Instructions were given to each man to shake the

composite samples each day so as to mix the fresh samples with the rest of the milk and keep the cream from becoming dry or hard on the sides of the bottle. The jars that were used for keeping the composite samples were one pint, tin top, covered bottles. When the period of weighing and sampling was completed the samples were tested either on the farm or at the creamery.

APPARATUS.

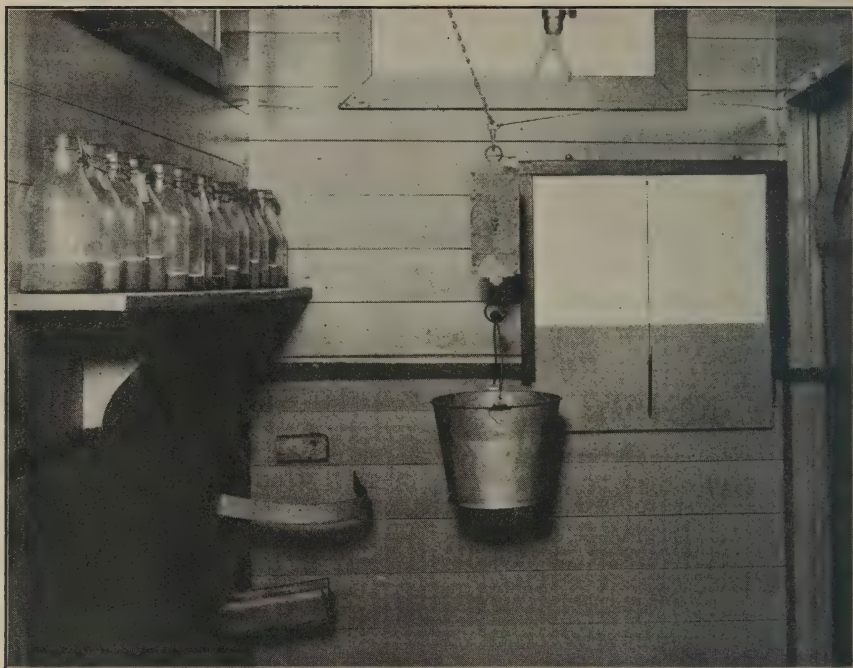
The things necessary for carrying on the work were: A spring scale for weighing the milk; a small dipper or milk thief for taking the samples; bottles for holding the composite samples; corrosive sublimate for preserving them; and milk sheets. All these were furnished by the Experiment Station. Each cow was given a name or number which was placed at the top of the milk sheet so that the weights of milk could be put directly under her name or number. Cut No. 1 shows all the necessary apparatus for carrying on the work, and Table I is a sample of a farmer's milk record.

TABLE I.—SAMPLE OF FARMER'S MILK RECORD FOR ONE WEEK, FROM JULY 30, P. M., TO AUGUST 6, A. M.

MILK—POUNDS.											
Number of the milking.	Spotty No. 1.	Black No. 1.	Black No. 2.	Bottle.	Milly.	Little Lamie.	Alice.	Belle.	Sleepy Eye.	Roaney.	Pet.
1	20.5	14.1	11.3	15.0	15.4	10.9	6.9	7.4	7.5	5.5	15.1
2	13.5	6.8	6.5	10.2	13.2	8.3	5.2	3.9	5.1	3.9	10.3
3	22.2	16.8	11.7	15.0	17.0	11.0	6.7	7.9	7.7	5.2	15.8
4	14.2	5.2	8.2	10.7	14.2	8.5	5.2	4.9	4.6	3.9	10.9
5	20.3	15.7	6.0	13.7	16.3	10.7	6.8	6.5	7.3	4.9	15.7
6	16.7	7.0	9.2	11.9	15.6	9.5	5.1	5.1	6.1	4.6	12.2
7	18.5	15.5	4.7	14.1	16.7	9.6	7.0	6.0	6.6	5.0	14.5
8	16.0	7.8	7.3	11.2	14.4	8.7	5.0	4.9	6.2	3.9	14.7
9	22.0	14.5	13.5	16.4	18.5	10.7	6.9	7.2	6.9	5.3	15.8
10	14.0	9.5	6.9	10.5	15.0	8.3	4.8	4.6	5.3	3.6	11.4
11	19.9	9.8	4.0	12.9	17.5	11.0	6.7	6.1	7.0	5.2	14.9
12	14.5	13.0	6.8	11.5	14.5	8.1	4.4	4.6	5.8	3.9	11.3
13	22.6	13.2	6.7	16.1	18.4	11.6	8.6	7.4	7.3	7.8	16.1
14	15.4	7.1	8.8	11.3	14.7	8.6	4.3	5.2	5.9	4.2	11.7
Total..	250.3	156.0	111.6	180.5	221.4	135.5	83.6	81.7	89.3	66.9	190.4
Fat, %	3.2	2.8	3.2	3.5	3.2	3.4	4.6	4.0	4.6	4.4	3.0
Fat, lb.	8.00	4.36	3.57	6.31	7.08	4.60	3.84	3.26	4.10	2.94	5.71

ARRANGING APPARATUS.

A considerable amount of time can be saved by arranging scales, sample bottles, and milk sheet in such a way that the weighing, recording the weight, and sampling the milk can be done with as few steps



CUT 1. SCALE FOR WEIGHING MILK. RECORD SHEET AND COMPOSITE SAMPLES.

and motions as possible. After the most desirable place in the barn has been chosen for weighing and sampling, the scales can be suspended from the ceiling so as to hang near the milk sheet which can be tacked to a board and hung on the wall, or fixed on an inclined shelf projecting from the wall. After the milk from each cow is weighed, a sample should be taken and placed in the jar bearing the cow's name or number. The sample bottles can be arranged on either side of the milk sheet, or if convenient, above it. If there are two or more milkers, the sample bottles can be arranged so that each milker will have his bottles together and arranged in the same order in which the cows are milked. This method saves time in finding the right sample bottle.

TIME CONSUMED IN WEIGHING AND SAMPLING.

The length of time required to weigh and sample the milk depends entirely upon the quickness of the man who is doing it. Some men will say that it takes but little time to weigh and sample each cow's milk, while others complain of the length of time necessary to do the work. It will take, on an average, about one minute to each cow, or two minutes a day. This indicates, for the seven weeks that it is done during the year,

about one hour and thirty-eight minutes for each cow tested. With this amount of time expended, the farmer can have a complete record of every cow in his herd. From this, with a knowledge of what he is feeding, he will know at the end of the year whether she has been a source of profit or loss to him; and furthermore, he will know from which cows to select heifers for his dairy. Considering the time that is consumed in doing this work, it seems strange that more dairymen do not have their herds tested. Many of them can weigh and sample each cow's milk every seventh week, and then have the buttermaker test the samples for them at the creamery. With the percent of fat and the weights of milk they can estimate for themselves the performance of every cow in their herds. The importance of doing this work will be shown further on in this bulletin.

CALCULATING THE AMOUNT OF MILK AND BUTTER FAT.

The milk was weighed and sampled during the fourth week of the seven-week periods. From the total amount of milk that each cow gave during this time, and the percent of fat, was calculated the amount of butter fat produced in the week. From these results were estimated the amount of milk and butter fat each cow produced during the three weeks before, and the three weeks following the test. The cow's yearly record was made up from these tests, and in this way the total amount of milk and butter fat that she produced during the entire year was determined. It may be objected to that this method did not secure results absolutely correct. On this it may be said that the chief object was to secure data from which cows could be compared with each other and that this object was fully attained even though the totals may have been either slightly too large or too small. Check methods show however, that the data are very close to the actual amounts produced. In many cases the dairymen also kept an approximate account of the grain and roughage that each cow consumed during the year. Where this was done the records are of exceptionally high value, for they clearly show the profit or loss of every cow kept in the dairy.

THE DIFFERENT METHODS THAT MAY BE USED IN WEIGHING AND SAMPLING.

There are several ways that records from each cow in the dairy can be obtained. The method used in obtaining the records given in this bulletin was as follows: The farmer, every seventh week, weighed and sampled each cow's milk for fourteen consecutive milkings. The amounts of milk yielded each day were added and from the percent of butter fat which the milk contained, was determined the amount of butter fat each cow produced during the week. From these results

were estimated the amount of milk and butter fat each cow produced the three weeks before and the three weeks following the test.

The Dairy Department of the Wisconsin Experiment Station had its patrons weigh and sample one day each week for the whole year. From the different weights and tests the amount of milk and butter fat that each cow produced in the entire year was estimated.

The testing of the milk each week is too much for the average farmer to do, but taking composite samples of milk of several milkings gives a very good average of the per cent of fat contained in the milk, and can be done by any one if he chooses. Fairly accurate results can be obtained by weighing and sampling the milk every thirteenth week and calculating the results the same way as when the weighing and sampling were done every seventh week. The method of weighing and sampling each cow's milk every seventh week for several consecutive milkings, or three and one-half days, gives very good results. The results can be multiplied by two which would equal the amount of milk and butter fat produced for one week, then estimated the same as if the weighing and sampling were done the entire week. The composite samples that are but three and one-half days old, are in better condition for testing than samples that are a week old. The farmers will take more pains with the work if it does not become tedious to them.

The accuracy of records obtained by weighing and sampling each cow's milk at regular times during the year is often doubted. As a check a comparison was made between the amount of milk and butter fat sold from two farms to a creamery and the amount of milk and butter fat as determined from weighing and sampling each cow's milk every seventh week for fourteen consecutive milkings during the year. In one case there was found a difference of 2.2 percent of butter fat, and .0015 percent in milk, making a difference of 4.67 pounds of butter fat and 8.09 pounds of milk per cow; in the other case a difference of .038 percent fat, and 1.98 percent in milk, or .27 pounds of butter fat and 120.3 pounds of milk per cow. From these results it is seen that by carefully weighing and sampling each cow's milk every seventh week during her period of lactation records can be secured which are substantially correct.

OBJECT OF THE WORK.

There is no better way of finding out the merits of a dairy animal when giving milk than to use the scales and the Babcock test. With the weights of milk produced, the percent of butter fat and the length of her milking season, together with the feed consumed, the value of a cow for the dairy can be determined. The object of getting dairymen to do this work is to determine which of the individual cows in their herds are the most profitable, so that the owners may cull out the poor

cows and keep the profitable ones; to show them the importance of better feeding and caring for their stock; and the importance of selecting better sires for their herds. A dairy animal should be selected for the amount of milk and butter fat which she yields during the year rather than on points of fancy or form. It is a reasonably safe rule in selecting dairy cows to go upon the results obtained from the scales and the Babcock test. If she is a good breeder, that also should be taken into consideration. If the performance of each cow in the herd is known, the heifers can be selected from the best cows and when these heifers become fresh the test should be applied to them and the inferior ones culled out. This can only be done when we have an intelligent understanding of each cow and her capability of producing milk and butter fat.

ELEMENTS OF DANGER IN THE USE OF SCALES AND BABCOCK TEST.

While the scales and Babcock test can be of great service in the selection of our dairy animals, they must, however, be used with judgment. Dairy cows have their "off years," and this must be considered when the herd is being culled. If we do not bear this fact in mind, we are apt to sell some of the best cows from our herds. The writer has in mind the cow Sweet Briar, of the Minnesota Experiment Station, that produced for ten years an average of 358.07 pounds of butter a year, while in 1898 she produced only 206.62 pounds of butter, but in 1899 she made 306.53 pounds, and in 1901 370.53 pounds. If the merits of Sweet Briar had been wholly based on the work she did in 1898 she would have been classed as a very ordinary cow, and perhaps sold. The great value of scales and Babcock test lies in their continued use in the dairy herd and not in one year's test. Good heifers usually come from the best dairy cows, but it sometimes happens that a promising heifer may do very poorly the first year. In such cases the heifer's individuality together with her breeding should be considered before she is sold. The testing of cows should, however, be carried on in every dairy if a systematic selection is to be made.

A good cow seldom has two "off years" in succession.

THE VARIATION IN FLOW AND PERCENT OF FAT IN MILK.

It has often been asked why it is necessary to weigh and sample each milking for a week. By weighing and testing each milking separately we usually find considerable variation in milk yield and fat content. The following tables show to what extent a cow will vary in quantity of milk and percent of fat from one milking to another. These tables are taken from records of cows that were tested for the Holstein-Friesian Advanced Registry.

TABLE 2.—SHOWING THE YIELD OF MILK AND PERCENT BUTTER FAT OF EACH MILKING FOR ONE WEEK.

ECHO BETTINA HERBERT'S RECORD.

1902.	Milk, lb.	Fat, %	Fat, lb.	Total milk, lb.	Total fat, lb.
March 10, Morning	12.3	4.60	.5658		
Noon	9.0	3.80	.3420		
Evening	10.1	3.30	.3333	31.4	1.2411
March 11, Morning	14.2	3.10	.4402		
Noon	10.0	3.20	.3200		
Evening	11.0	3.00	.3300	35.2	1.0902
March 12, Morning	15.6	3.70	.5772		
Noon	11.0	4.20	.4620		
Evening	10.9	3.80	.4142	38.5	1.4532
March 13, Morning	17.6	3.30	.5808		
Noon	12.2	4.05	.4941		
Evening	12.0	3.30	.3960	41.8	1.4709
March 14, Morning	16.5	3.10	.5115		
Noon	12.2	3.70	.4514		
Evening	11.7	3.35	.39195	40.4	1.35485
March 15, Morning	18.0	3.50	.6300		
Noon	12.6	4.20	.5292		
Evening	12.3	4.10	.5043	42.9	1.6635
March 16, Morning	17.2	3.50	.6020		
Noon	13.0	4.20	.5460		
Evening	12.8	3.60	.4608	43.0	1.6088

MAID CLOVERDALE'S RECORD.

Sept. 23, Morning	18.1	2.80	.506		
Noon	11.5	3.00	.345		
Evening	15.7	3.00	.471	45.3	1.322
Sept. 24, Morning	18.4	4.20	.772		
Noon	13.0	3.10	.403		
Evening	15.6	2.60	.405	47.0	1.580
Sept. 25, Morning	16.7	2.00	.334		
Noon	16.4	3.30	.541		
Evening	13.4	2.80	.375	46.5	1.250
Sept. 26, Morning	17.3	2.60	.449		
Noon	18.0	4.50	.810		
Evening	11.9	2.40	.285	47.2	1.544
Sept. 27, Morning	20.4	2.70	.550		
Noon	14.5	2.90	.420		
Evening	15.2	2.80	.425	50.1	1.395
Sept. 28, Morning	18.5	3.80	.703		
Noon	14.5	2.80	.406		
Evening	14.5	2.30	.333	47.5	1.442
Sept. 29, Morning	20.9	3.20	.668		
Noon	14.3	2.40	.343		
Evening	15.9	3.00	.477	51.1	1.488

The above table readily shows the importance of weighing and sampling the milk for more than one milking, if the average test of the

cow is to be obtained. Maid of Cloverdale, for example, tested on the morning of September 25, two percent, and at noon, September 26, 4.50 percent. Had either been taken as her actual test it would have been very misleading, for her average test for that particular week was 2.99 percent.

THE BASIS UPON WHICH THE PROFIT OR LOSS OF THE COW IS COMPUTED.

It is very difficult to express the true value of the dairy cow in dollars and cents. But since the profit or loss of most of the cows tested has been given, it is perhaps well to state the basis upon which the profit or loss was calculated. The value of the product that the cow yielded was based upon the amount of butter fat that she made, and the market price of butter fat at the time.

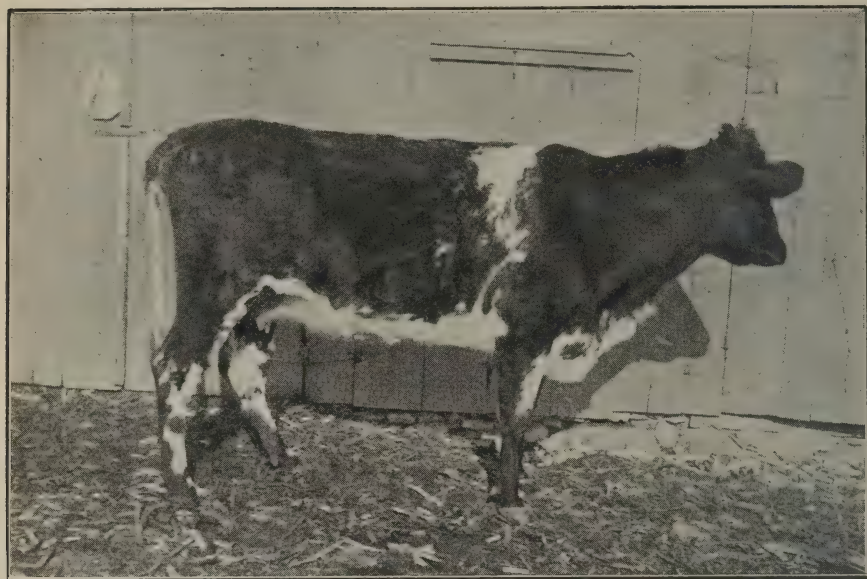
The value of the skim milk, the value of the calf, and the value of the manure produced by the cow were not credited to her, while on the other hand the cow was not debited with the amount of labor expended in her care nor the amount of feed she consumed when dry. The cow was simply credited with the amount of butter fat she produced, and charged for feed consumed when she was giving milk. The calf will usually pay for the cow's board when dry and the skim milk for the labor it takes to care for her. This method of calculation is, perhaps, a little unjust to some cows, for it is possible to have two cows yield the same amount of butter fat and one give a profit and the other a loss. If, for example, one milks ten months and the other but six months in the year to yield equal amounts of butter fat, which sometimes happens, one cow is charged with ten month's feed and the other with only six month's.

Red Bird in herd "B" and Duchess in herd "C" are examples of this kind. Red Bird milked ten months and charged \$1.28 cents for her board, and Duchess milked six months and gave a profit of \$9.16, and each yielded the same amount of butter fat.

The rations for the cows were not weighed each day. A number of dishes of meal was weighed in order to get the average amount of feed that the measure held and the number of dishes that each cow received a day was recorded. Cut and shredded corn stover and ensilage were estimated in the same manner. The hay was also weighed at different times.

REPORT OF HERD "A."

Herd "A" was composed of natives, grade Shorthorns, grade Jerseys, and grade Holsteins. The average weight of each cow was 1,000 pounds. The herd was not bred for dairy purposes. Moreover, they



CUT 2. COW NO. 6, HERD A, GAVE IN ONE YEAR 1,838 LB. MILK;
AVERAGE TEST, 4.43%; 95 LB. BUTTER.

neither showed dairy form nor capabilities of giving large flows of milk, nor producing large amounts of butter fat. Nearly every cow showed some signs of disorder. They were not in a thrifty condition. A number of them aborted during the year, while others failed to get with calf and were sold. Some of them were disposed of so early in the test that their records are not calculated with the rest of the herd.

There were ten cows kept in this herd whose milk was not weighed or tested. It is unfortunate that the owner could not see the importance of weighing and testing each one of these cows, but the average amount of milk and butter fat that each of the untested cows produced for the year will be given, for a record of the amount of milk and butter fat that was sold from all the cows was kept.

The herd did not yield the amount of milk and butter fat that it should for the amount of grain consumed. While the owner did not keep an accurate enough account of the grain and roughage each cow ate to be reported upon, he fed a ration to his cows that was largely made up of corn and other foods rich in carbohydrates and containing a small per cent of protein. The cows received a small allowance of bran with the corn meal from October 1 to January 1. During the months of January and February, to the cows giving the largest flows of milk, was given the following:

RATION 1.

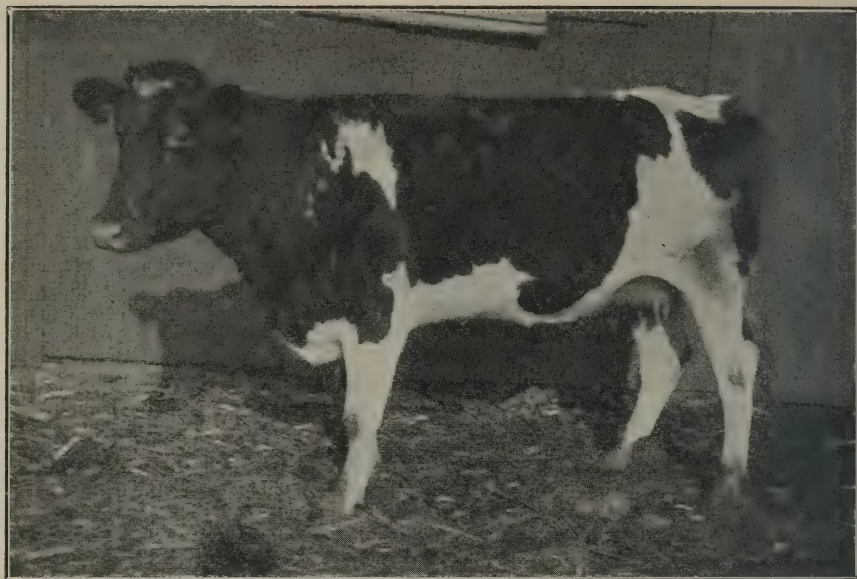
Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Corn meal	10	8.91	.790	6.670	.430	10c
Silage	35	7.31	.315	3.955	.245	3.5c
Timothy hay	10	8.68	.280	4.34	.140	5c
Total nutrients		24.90	1.385	14.965	.815	18.5c

This ration was altogether too rich in carbohydrates and contained a very low per cent of protein. If this farmer had sold more of his corn and bought some mill feed he would, with less expense, have improved the ration. For example, a ton of corn meal would at this time have paid for more than a ton of grano-gluten. If a ration were made from five pounds of grano-gluten and three pounds of corn meal with the same amount and kind of roughage as contained in the above, the ration would be far better and cheaper. Such a ration would contain the following nutrients:

RATION 2.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Grano-gluten	5	4.71	1.335	1.94	.620	4.5c
Corn meal	3	2.67	.237	2.001	.129	3c 1/2
Silage	35	7.31	.315	3.955	.245	3.5c
Timothy hay	10	8.68	.280	4.340	.140	5c
Total nutrients		23.38	2.167	12.236	1.134	16.0c

A number of the cows' udders became feverish and hard during the time that they were being fed so much corn. Four of them were giving milk from only three teats. It seems that excessive corn feeding must have had something to do with the general unsatisfactory condition of the herd, especially in the months of January and February, and perhaps the cause of four of them losing the use of one-quarter of their udders. The rye and corn meal were mixed equal parts by weight, and about eight pounds of the mixture, together with timothy hay and corn silage, was the ration they received until May 1, when ground oats was substituted in the place of rye. The cows were turned out to pasture about May 25, but were given a small allowance of silage to July 1. From this time on to the completion of the year's work they received nothing but grass. The ration which the cows received from March 1 to May 1 was somewhat better than the ration fed in January and February, but it could have been much improved with mill feed. The ration for fresh cows was about as follows:



CUT 3. COW NO. 10, HERD A, GAVE IN ONE YEAR 3,833 LB. MILK;
AVERAGE TEST, 3.37%; 150 LB. BUTTER.

RATION 3.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Rye	4	3.54	.396	2.704	.044	4.0c
Crushed corn and cob meal	4	3.40	.176	2.400	.116	4.0c
Silage	35	7.31	.315	3.955	.245	3.5c
Timothy hay	7	6.08	.196	3.038	.098	3.5c
Total nutrients		20.33	1.083	12.097	.503	15.0c

It will be noticed that this ration which contains but 1.083 pounds of protein costs nearly as much as Ration 2, which contains 2.167 pounds of protein. It readily shows that by exchanging some of the home-grown grain for mill stuff the ration could not only have been made better but actually cheaper. It can be said that the cows in this herd did a very ordinary year's work, but considering the individuality of each animal in the herd, the general condition of their health, together with unskillful feeding, it is not at all surprising that the results are no better.



CUT 4. COW NO. 15, HERD A, GAVE IN ONE YEAR 6,145 LB. MILK;
AVERAGE TEST, 3.63%; 260 LB. BUTTER; NET PROFIT, \$18.40.

YEARLY RECORD OF BEST AND POOREST COW IN HERD "A," AND AVERAGE FOR
ENTIRE HERD.

	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
Best cow, No. 15.....	6,145	3.63	223	260
Poorest cow, No. 37	1,482	3.97	58	68
Average record of cows tested	3,970	3.55	141	164
Average record of entire herd	3,361	3.55	119	139

It was found that the average cow must produce about 140 pounds of butter fat last year to pay for her board, since the average price for butter fat, when sold to the creameries, was twenty-two cents. Calculating the results upon that basis, the cows that were tested yielded a profit of twenty-three cents. To ascertain the amount of product yielded by each of the untested cows in the herd for the year, it was necessary to subtract the amount of milk and butter fat yielded by the eighteen cows that were tested from the total amount of milk and butter fat that was sold from this dairy. In this calculation a liberal amount of milk was estimated for house use and for feeding of calves.

Total amount of milk sold from Farm "A".....	97,720	lb.
" " " yielded by tested cows.....	76,060	"
" " " " the ten untested cows,.....	21,660	"

The average amount of milk yielded by each untested cow . . .	2,166	lb.
" total amount of butter fat sold from Farm "A"	3,554	"
" " " yielded by tested cows	2,751	"
" " " " ten untested cows . . .	803	"
" average amount of butter fat yielded by each cow untested	80	"

Calculating for the whole herd, and estimating that it takes 140 pounds of butter fat to pay for a cow's board, there is a loss of \$4.54 a cow, or each cow should have produced 20.64 pounds more butter fat to have paid for her keep.

The best cow in this herd gave a profit of \$18.40, while the poorest was kept at an actual loss of \$17.83.

TABLE 3.—RECORD OF EACH COW IN HERD "A" FOR ONE YEAR.

GROUP 1.—COWS YIELDING LESS THAN 100 LB. OF BUTTER FAT.								
No. of cow.	Age, years.	Breed.	Date of calving.	Milk, lb.	Fat, per-cent.	Fat, lb.	Lb. of butter.	Days in milk.
37	12	Grade Jersey	11- 8-01	1482*	3.97	58	68	147
6	3	Native	5-29-02	1838	4.43	81	95	210
25	8	Native	2-13-02	2470	3.87	95	111	210

GROUP 2.—COWS YIELDING LESS THAN 140 LB. OF BUTTER FAT.

1	4	Grade Shorthorn	10-25-02	3176	3.45	109	128	196
31	10	Grade Shorthorn	1-17-02	3535	3.18	112	131	245
8	3	Native	9- 6-01	2740	4.16	114	133	259
10	4	Native	3- 5-02	3833	3.37	129	150	245
34	10	Grade Shorthorn, Abr. . . .	12- 5-01	4474	2.97	133	155	294
46	3	Native	1- 8-02	3766	3.67	138	161	259

GROUP 3.—COWS YIELDING LESS THAN 175 LB. OF BUTTER FAT.

33	10	Grade Holstein	4- 9-02	3550	3.94	140	163	210
30	9	Native { Abr.	9-29-02	4306	3.55	153	178	299
		{ Clv.	12-18-01					
29		Native, Abr.	3-21-02	3916	4.00	156	183	210
4	3	Native	4-13-02	3651	4.31	157	183	365
44	4	Native	11-16-01	5082	3.15	160	186	294

GROUP 4.—COWS YIELDING LESS THAN 225 LB. OF BUTTER FAT.

13	4	Grade Holstein	2-25-02	4895	3.87	189	221	290
2	4	Grade Holstein	10-30-01	6824	2.80	191	223	308
16	9	Grade Holstein	1- 4-01	5776	3.33	192	224	308
15	9	Grade P. S. H.	11- 4-01	6145	3.63	223	260	294

* The tenth's place in the "milk" column and the tenth's and hundredth's places in the "butter fat" and "butter" columns have been eliminated for the convenience of the reader. The average "percent fat," the average production, and the profit or loss of the herd, however, were figured before the elimination. This method not only applies to herd "A," but to all the herds tested.

THE REPORT OF HERD "B."

This herd was composed largely of common native and grade Holstein cows. There were a number of fairly good dairy cows in the herd and a number of promising heifers. The cows weighed an average, about 1,050 pounds. The general health of the herd was good. A few of the cows aborted during the year and some of them had caked udders. A few of them were sold on this account. A number of them were disposed of so early in the test that their records are not calculated with the rest of the herd but are given separately. On the whole it can be said that the cows received good care and were fairly well fed throughout the year.

The cows were fed from October 1 to November 1, some ear corn and stalks and pasture. During the months of November and December, the cows received the following:

RATION 4.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Bran	6	5.31	.774	2.406	.204	5.4c
Corn meal	6	5.35	.474	4.002	.258	6.0c
Millet hay	8	7.04	.256	3.880	.080	4.0c
Corn stover	10	5.95	.170	3.240	.070	2.0c
Total nutrients		23.65	1.674	13.528	.612	17.4c

This ration would have been considerably better if two pounds of oil meal or gluten meal had been substituted for three pounds of corn meal and would have cost no more.

During the months of January and February the fresh cows received seven pounds of bran, four pounds of corn meal, oat straw, and corn stover *ad libitum*.

In March and April they received a ration about as follows:

RATION 5.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Bran	6	5.31	.774	2.406	.204	5.4c
Gluten feed	3	2.70	.699	1.521	.081	3.3c
Clover hay	5	4.23	.340	1.790	.085	2.5c
Corn stover	8	4.76	.136	2.592	.056	1.6c
Total nutrients		17.00	1.949	8.309	.426	12.8c
Oat straw, <i>ad libitum</i> .						

This is a balanced ration and contains enough nutrients for cows giving large flows of milk. If some succulent food, such as roots or silage, had been added, it would have been still better.

In May, the fresh cows or the ones giving the most milk, received the following:

RATION 6.

Food stuffs.	Lb.	Dry matter.	Pro-tein.	Carbohy- drates.	Fat.	Cost.
Shorts	7	6.17	.854	3.50	.266	6.3c
Gluten feed.....	3	2.70	.699	1.521	.081	3.3c
Clover hay	5	4.23	.340	1.790	.085	2.5c
Millet hay	8	7.04	.256	3.880	.080	4.0c
Total nutrients		20.14	2.149	10.691	.512	16.1c

This is another very good ration as it supplies enough nutriment for a cow producing 350 pounds of butter fat a year. Each cow in the herd during the rest of the year received two pounds of shorts a day, besides plenty of blue grass pasture.

YEARLY RECORD OF BEST AND POOREST COW IN HERD "B," AND AVERAGE FOR ENTIRE HERD.

	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
Best cow, Hartwell No. 2	6,197	3.99	247	288
Poorest cow, Brindle No. 1	3,731	2.88	107	125
Average record of entire herd	5,360	3.52	188	220

Spotty No. 1 charged to produce 100 pounds of milk, 40.7 cents and 12.6 cents for one pound of butter fat.

Red Bird charged to produce 100 pounds of milk, 70.9 cents, and 23.2 cents for one pound of butter fat.

The average cost of this herd to produce 100 pounds of milk was 57.0 cents and 16.1 cents to make one pound of butter fat.

Spotty No. 1 gave a profit of \$25.32 and Red Bird charged \$1.28 for her board.

The average profit of each cow was \$12.12.

The average price of grain and roughage from September 1, 1901, to September 1, 1902, was about as follows:

Bran	\$18.00	per ton.	Oil meal.....	\$28.00	per ton.
Shorts	18.00	"	Clover hay	10.00	"
Corn meal.....	20.00	"	Timothy hay	10.00	"
Corn cob meal ...	20.00	"	Millet hay	10.00	"
Grano-gluten	18.00	"	Corn stover.....	4.00	"
Gluten meal	28.00	"	Corn silage.....	2.00	"
Gluten feed	22.00	"	Pasture	\$1.00	per month.



CUT 5. SPOTTY NO. 1, HERD B, GAVE IN ONE YEAR 7,711 LB. MILK;
AVERAGE TEST, 3.20%; 288 LB. BUTTER; NET PROFIT, \$25.32.



CUT 6. RED BIRD, HERD B, GAVE IN ONE YEAR 4,974 LB. MILK;
AVERAGE TEST, 3.04%; 176 LB. BUTTER; NET LOSS, \$1.28.

The price of grain is based upon purchase price in the city market and the price of roughage is based upon the purchase price at the farm. When the cow is charged the above prices for farm products the farmer receives a profit on his land and the profit which the cow gives him is over and above what he could have received for his products if he had sold them upon the market, and moreover, the cows are often fed that which is not marketable. Take corn stover for example, what would it be worth if it was not for the live stock kept upon the farms?

The average prices of butter fat when sold to the creameries for the different months, were as follows:

September, 1901.....	19c	April, 1902.....	26c
October, 1901	19c	May, 1902	22c
November, 1901	20c	June, 1902.....	21c
December, 1901	22c	July, 1902	20.5c
January, 1902.	24c	August, 1902	19c
February, 1902.	28c	September, 1902	20.5c
March, 1902	28c	October, 1902	23c

TABLE 4.—SHOWING PROFIT OR LOSS FOR EACH COW IN HERD "B" FOR ONE YEAR.

GROUP 1. KEPT AT A LOSS.

Name of cow.	Milk, lb.	Fat, %	Fat, lb.	Lb. but- ter.	Gross returns.	Cost of feed.	Profit or loss.
Red Bird.....	4,974	3.04	151	176	\$33.99	\$35.27	\$1.28
Belle	4,412	3.38	149	174	33.26	34.30	1.04
Brindle No. 1	3,731	2.88	107	125	25.41	26.41	1.00

GROUP 2.—KEPT AT A SMALL PROFIT.

Alice	4,231	3.97	168	196	\$38.61	\$34.30	\$4.31
Little Lamie	3,956	3.05	120	140	27.32	21.95	5.37
Harry Cow.....	4,891	3.14	153	179	35.00	27.93	7.07
Sleepy Eye	4,190	4.20	176	205	40.53	31.67	8.86

GROUP 3.—KEPT AT A FAIR PROFIT.

Black No. 2	5,474	3.53	193	225	\$44.28	\$32.91	\$11.37
Spotty No. 2	6,720	3.34	224	262	50.85	38.51	12.34
Roaney.....	5,705	3.94	225	262	52.43	39.46	12.97
Dora	4,989	3.70	184	215	39.51	26.40	13.11
Black No. 1	6,179	3.05	188	220	44.36	30.71	13.65

GROUP 4.—KEPT AT A GOOD PROFIT.

Hartwell No. 2	6,197	3.99	247	288	\$55.47	\$30.49	\$24.98
Spotty No. 1	7,711	3.20	247	288	56.73	31.41	25.32

TABLE 4—Continued.

GROUP 5.—KEPT AT A VERY FAIR PROFIT.

Name of cow.	Milk, lb.	Fat, %	Fat, lb.	Lb. but- ter.	Gross returns.	Cost of feed.	Profit or loss.
Bottle	5,450	3.66	199	232	\$42.79	\$27.37	\$15.42
Beauty	6,402	3.82	245	285	53.62	36.79	16.83
Hartwell No. 1	4,421	4.20	186	217	38.24	21.10	17.14
Brindle No. 2	4,683	3.43	161	187	38.52	20.85	17.67
Clara	6,101	3.89	237	277	54.85	35.95	18.90
Pet	6,793	3.10	211	246	48.60	28.18	20.42

TABLE 5.—RECORD OF EACH COW IN HERD "B" FOR ONE YEAR.

GROUP 1.—COWS YIELDING LESS THAN 160 LB. OF BUTTER FAT.

Name of cow.	Age, yr.	Breed.	Date of calving.	Milk, lb.	Fat, %	Fat, lb.	Lb. but- ter.	Days in milk.
Brindle, No. 1	15	Native ...	2- 2-02	3,731	2.88	107	125	203
Little Lamie	8	"	3- 1-02	3,956	3.05	120	140	275
Belle	3	Gr. Holst.	11-10-01	4,412	3.38	149	174	290
Red Bird	6	"	9-30-01	4,974	3.04	151	176	300
Harry Cow.....	10	"	2- 3-02	4,891	3.14	153	179	240

GROUP 2.—COWS YIELDING LESS THAN 200 LB. OF BUTTER FAT.

Brindle No. 2	4	Native ...	.....	4,683	3.43	161	187	210
Alice	3	Gr.Holst.	11-13-01	4,231	3.97	168	196	287
Sleepy Eye.	5	Native ..	12-25-01	4,190	4.20	176	205	320
Dora	6	Gr. Holst.	3-21-02	4,989	3.70	184	215	310
Hartwell No. 1	8	Native ..	5-27-02	4,421	4.20	186	217	270
Black No. 1	8	Gr.Holst.	1-28-02	6,179	3.05	188	220	275
" 2	4	"	2-21-02	5,474	3.52	193	225	340
Bottle	5	"	4-11-02	5,450	3.66	199	232	300

GROUP 3.—COWS YIELDING LESS THAN 250 LB. OF BUTTER FAT.

Pet	5	Gr.Holst.	2-12-02	6,793	3.10	211	246	260
Spotty No. 2	8	Native ...	9-24-01	6,720	3.34	224	262	300
Roaney.....	7	"	11- 7-01	5,705	3.94	225	262	305
Clara	5	Gr. Holst.	10- 1-01	6,101	3.89	237	277	300
Beauty	4	Native ...	10- 5-01	6,402	3.82	245	285	305
Spotty No. 1	12	"	7-31-02	7,711	3.20	247	288	280
Hartwell No. 2	12	"	2-21-02	6,197	3.99	247	288	267
			3- 1-02					

REPORT OF HERD "C."

This herd was composed of natives, grade Shorthorns, grade Holsteins, one Red Poll and two grade Jerseys. The average weight of the cows was about 1,050 pounds and they were in good health during the whole year. There were no abortions or caked udders during the time the test was made. A number of the cows were sold early in the test because of their rapid falling off in milk flow when about three

months along in the period of lactation. This is a very common fault with a great many cows kept in the dairy, and it is not noticed by the owners so much as it should be. They remember the cow when she gave a full pail of milk. The herd received good care during the year and was kept in a warm barn during the winter where it received a fairly good ration. The fresh cows in October to November were fed daily about three pounds of bran, shock corn, and pasture. From November 15 to January 1, the ration consisted of the following feeds: Bran, five pounds; corn meal, three pounds; corn stover, *ad libitum*. If the farmer could have given his cows ten pounds of alfalfa or clover hay and less corn stover it would have been a considerably better ration.

In January and February a little better ration was fed. It was about as follows:

RATION 7.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Bran	5	4.42	.645	2.005	.170	4.5c
Corn meal	5	4.45	.395	3.335	.215	5.0c
Gluten feed	1	.90	.233	.507	.027	1.1c
Timothy hay	5	4.34	.140	2.170	.070	2.5c
Corn stover	12	7.14	.204	3.888	.084	2.4c
Total nutrients		21.25	1.617	11.905	.566	15.5c



CUT 7. CRAZY, HERD C, GAVE IN ONE YEAR 6,945 LB. MILK;
AVERAGE TEST, 4.23%; 343 LB. BUTTER; NET PROFIT, \$31.55.



CUT 8. DUCHESS, HERD C, GAVE IN ONE YEAR 4,229 LB. MILK;
AVERAGE TEST, 3.59%; 177 LB. BUTTER; NET PROFIT, \$9.16.



CUT 9. JERSEY, HERD C, GAVE IN ONE YEAR 5,498 LB. MILK;
AVERAGE TEST, 4.48%; 287 LB. BUTTER; NET PROFIT, \$34.77.

This ration would have been still better if the corn meal had been reduced two pounds and gluten feed increased to four pounds. During the months of March, April, and May, to the cows giving the largest flow of milk were given the following:

RATION 8.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Bran	5	4.42	.645	2.005	.170	4.5c
Gluten feed	2	1.80	.466	1.014	.054	2.2c
Oil meal	1	.91	.293	.327	.078	1.4c
Timothy hay	15	13.02	.420	6.510	.210	7.5c
Total nutrients.....		20.15	1.824	9.856	.512	15.6c

The cows were turned out to pasture about May 20, and as soon as grass was plentiful they received no grain during the rest of the test. They, however, received some forage in connection with the pasture. Green peas and oats were fed in July, and in August green sorghum. It can be said that the herd was well cared for the whole year, and moreover, every cow was fed as near as possible according to the amount of milk and butter fat that she was yielding. It must be borne in mind that the rations given above were fed to cows that were producing the most milk and butter fat and not to the strippers.

YEARLY RECORD OF BEST AND POOREST COW IN HERD "C," AND AVERAGE FOR ENTIRE HERD.

	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
Best cow, Crazy.....	6,945	4.23	294	343
Poorest cow, Harrison	2,721	3.96	108	126
Average yield of entire herd.....	4,942	3.90	192	224

Jersey produced butter fat the cheapest. She charged 29.7 cents to produce 100 pounds of milk, and 6.6 cents to make one pound of butter fat.

Harrison charged 97.7 cents to make 100 pounds of milk, and 24.6 cents to make one pound of butter fat.

The average cost of this herd to produce 100 pounds of milk was 55.5 cents, and 14.2 cents to produce one pound of butter fat.

Jersey gave a profit of \$34.77, and Harrison charged \$1.27 for her keeping.

The average profit for each cow in the herd was \$16.22.

TABLE 6.—SHOWING PROFIT OR LOSS FOR EACH COW IN HERD "C" FOR ONE YEAR.

GROUP 1.—KEPT AT A LOSS.							
Name of cow.	Milk, lb.	Fat, %	Fat, lb.	Lb. but- ter.	Gross returns	Cost of feed.	Profit or loss.
Harrison.....	2721	3.96	108	126	\$25.34	\$26.61	\$1.27
Ella	3,519	3.64	128	149	29.12	30.98	1.86
GROUP 2.—KEPT AT A SMALL PROFIT.							
White Face.....	3,865	3.56	137	160	\$31.69	\$31.30	\$.39
Millie	4,118	3.83	157	184	36.68	28.29	8.39
Duchess.....	4,229	3.59	151	177	37.47	28.31	9.16
GROUP 3.—KEPT AT A FAIR PROFIT.							
Victoria	2,979	4.34	129	151	\$26.28	\$15.81	\$10.47
Little Brownie	5,121	3.75	192	224	45.18	32.60	12.58
Lady	5,015	3.94	197	230	42.71	27.72	14.99
GROUP 4.—KEPT AT A VERY FAIR PROFIT.							
Pet	5,590	3.43	191	223	\$45.15	\$25.66	\$19.49
Old Line Back	5,926	3.55	210	245	50.34	28.47	21.87
Queen	4,857	3.73	181	211	38.90	21.61	17.29
Black Hawk	6,500	3.99	259	303	58.52	34.88	23.64
Babe	5,186	4.68	242	283	54.78	33.60	21.18
GROUP 5.—KEPT AT A GOOD PROFIT.							
Stubbornness.....	5,924	3.50	207	242	\$45.19	\$20.39	\$24.80
Roaney.....	6,013	3.97	238	278	57.46	29.00	28.46
Crazy	6,945	4.23	294	343	66.77	35.22	31.55
Jersey	5,498	4.48	246	287	51.15	16.38	34.77

TABLE 7.—RECORD OF EACH COW IN HERD "C" FOR ONE YEAR.

GROUP 1.—COWS YIELDING LESS THAN 160 LB. OF BUTTER FAT.								
Name of cow.	Age, yrs.	Breed.	Date of calving.	Milk, lb.	Fat, %	Fat, lb.	Lb. of butter	Days in milk.
Harrison.....	2	Gr. Holst.	7- 6-01	2,721	3.96	108	126	246
Ella	2	"	9-25-01	3,519	3.64	128	149	295
Victoria	4	"	6- 5-02	2,979	4.34	129	151	214
White Face	2	"	9-15-01	3,865	3.56	137	160	290
Duchess	8	Native ...	1- 2-02	4,229	3.59	151	177	197
GROUP 2.—COWS YIELDING LESS THAN 200 LB. OF BUTTER FAT.								
Millie	2	Gr. Holst.	10-20-01	4,118	3.83	157	184	330
Queen	4	Gr. S. H. .	3-28-02	4,857	3.73	181	211	260
Pet		Gr. Holst.	11-26-01	5,590	3.43	191	223	305
Little Brownie..	8	Native ...	10- 3-01	5,121	3.75	192	224	245
Lady	9	Gr. S. H. .	3-28-02	5,015	3.94	197	230	303

TABLE 7—Continued.

GROUP 3.—COWS YIELDING LESS THAN 300 LB. OF BUTTER FAT.

Name of cow.	Age, yrs.	Breed.	Date of calving.	Milk, lb.	Fat, %	Fat, lb.	Lb. of butter.	Days in milk.
Stubbornness ..	9	Gr. Holst.	3-29-02	5,924	3.50	207	242	246
Old Line Back ..	12	Native ...	12-20-02	5,926	3.55	210	245	250
Roaney.....		Gr. S. H..	1- 5-02	6,013	3.97	238	278	245
Jersey	9	Gr. Jer. ..	1- 3-02	5,498	4.48	246	287	275
Babe	6	"	10- 3-01	5,186	4.68	242	283	365
Black Hawk ...	4	Gr. Holst.	9-26-01	6,500	3.99	259	303	335
Crazy	10	Gr.Red P.	10- 4-01	6,945	4.23	294	343	335

REPORT OF HERD "D."

The cows in this herd consisted of full blood Jerseys, grade Jerseys, full blood Holsteins, grade Holsteins, natives, and grade Shorthorns. There were sixty cows in the herd when the test began and forty-seven of them remained through the year. Thirteen of the cows were sold during the time the test was being made for they were found to be inferior and unprofitable animals. The herd contained a great many very fine dairy cows and they made some very good records. The cows were in a good condition during the whole year and were kept in a scrupulously clean and well-ventilated barn which was scrubbed once a day and white washed twice a year. The sanitary condition was nearly perfect. The cows were not only well cared for, but they received well balanced rations during the entire year. The results of this herd readily show the importance of taking good care of dairy cows and of feeding them well. Some of the rations that the herd received at different times during the year show clearly how well these cows were fed.

From September 1 to the middle of October, to the cows giving the largest flow of milk, the rations consisted of six pounds of grano-gluten and all the green corn that they would eat up clean. From October 15 to December 7, the ration to the best milkers was about as follows:

RATION 9.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Grano-gluten	5	4.71	1.335	1.940	.62	4.5c
Corn meal	3	2.67	.237	2.001	.129	3.0c
Corn silage	45	9.40	.405	5.085	.315	4.5c
Timothy hay	5	4.34	.140	2.170	.070	2.5c
Total nutrients.....		21.12	2.117	11.196	1.134	14.5c

The ration fed from December 7 to February 1 was as follows:

RATION 10.

Food stuffs.	Lb.	Dry matter.	Pro-tein.	Carbohy- drates.	Fat.	Cost.
Shorts	3	2.65	.366	1.50	.114	2.7c
Corn meal	2	1.78	.158	1.334	.086	2.0c
Gluten meal	3	2.64	.963	1.236	.075	4.2c
Corn silage	45	9.40	.405	5.085	.315	4.5c
Hay	5	4.34	.140	2.170	.070	2.5c
Total nutrients.....		20.81	2.032	11.325	.660	15.9c

The cows seemed to do better when fed grano-gluten and corn meal than when they were fed shorts, corn meal, and gluten meal.

The ration from February 1 to March 15 was five pounds of grano-gluten, three pounds of corn meal, and fifty pounds of silage and timothy hay. From this time on until the cows were turned out to grass, they received about the following:

RATION 11.

Food stuffs.	Lb.	Dry matter.	Pro-tein.	Carbohy- drates.	Fat.	Cost.
Grano-gluten	7	6.60	1.869	2.716	.868	6.3c
Corn meal	3	2.67	.237	2.001	.129	3.0c
Silage	60	12.54	.540	6.780	.420	6.0c
Total nutrients.....		21.81	2.646	11.497	1.417	15.3c

It will be noticed that this ration contains no hay, corn silage being the only roughage that the cows received. The cows did very well on this ration and when they were turned out to pasture, which was about June 1, they were in good condition. In June the cows received about four pounds of grano-gluten a day, besides a grass pasture.

In July and August they received nothing but pasture grass. The above rations apply more to the general feeding of the best milkers in the herd, the strippers and poor milkers getting according to the amount of milk they were producing.

It should be observed that the rations given to the cows during the year did not contain a large amount of grain, but each one contained a liberal amount of nutrients for cows that were giving a large flow of milk and yielding large amounts of butter fat. It will also be noticed that each ration contained over two pounds of protein. This can be accounted for when grano-gluten is compared with bran or oats, for it contains twice as much digestible protein. Therefore, it is not necessary to feed so many pounds of the grano-gluten as we would have to feed of bran or oats to get the same amount of digestible protein.

The above facts are mentioned so that the reader will not be misled when he compares the total amount of grain that each cow in this herd consumed with the total amount of grain consumed by each cow in some other herd. When the cows in this herd were not receiving grano-gluten they were receiving gluten meal which is a by-product of glucose refining companies. This feed is also very rich in protein. It contains about thirty-two per cent of digestible protein. These facts demonstrate very clearly that it often pays farmers to sell some of their oats or corn and buy some such by-products as gluten meal, gluten feed, grano-gluten, oil meal, or dried brewer's grains, etc.

YEARLY RECORD OF BEST AND POOREST COW IN HERD "D," AND AVERAGE FOR ENTIRE HERD.

	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
Best cow, No. 129	8,949	4.52	404	472
Poorest cow, No. 324.....	3,364	4.06	136	159
Average record of entire herd	5,911	4.45	263	306

Cow No. 147 made butter fat the cheapest. She charged 7.5 cents to produce one pound of butter fat and 35.5 cents to produce 100 pounds of milk.



CUT 10. COW NO. 283, HERD D, GAVE IN ONE YEAR 10,151 LB. MILK; AVERAGE TEST, 3.68%; 436 LB. BUTTER; NET PROFIT, \$45.36.



CUT 11. COW NO. 317, HERD D, GAVE IN ONE YEAR 10,059 LB. MILK;
AVERAGE TEST, 3.79%; 445 LB. BUTTER; NET PROFIT, \$48.94.



CUT 12. COW NO. 147, HERD D, GAVE IN ONE YEAR 7,890 LB. MILK;
AVERAGE TEST, 4.70%; 432 LB. BUTTER; NET PROFIT, \$57.22.



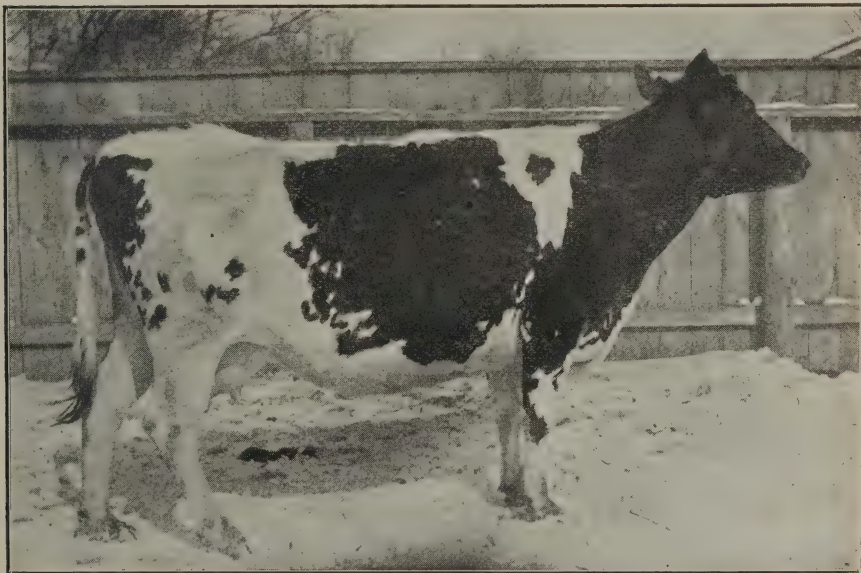
CUT 13. COW NO. 199, HERD D, GAVE IN ONE YEAR 6,132 LB. MILK;
AVERAGE TEST, 4.75%; 340 LB. BUTTER; NET PROFIT, \$31.54.



CUT 14. COW NO. 44, HERD D, GAVE IN ONE YEAR 3,399 LB. MILK;
AVERAGE TEST, 4.58%; 181 LB. BUTTER; NET LOSS, 18 CENTS.



CUT 15. COW NO. 184, HERD D, WITH TWO QUARTERS OF HER UDDER GONE,
GAVE IN ONE YEAR 7,997 LB. MILK; AVERAGE TEST, 4.77%;
445 LB. BUTTER; NET PROFIT, \$49.42.



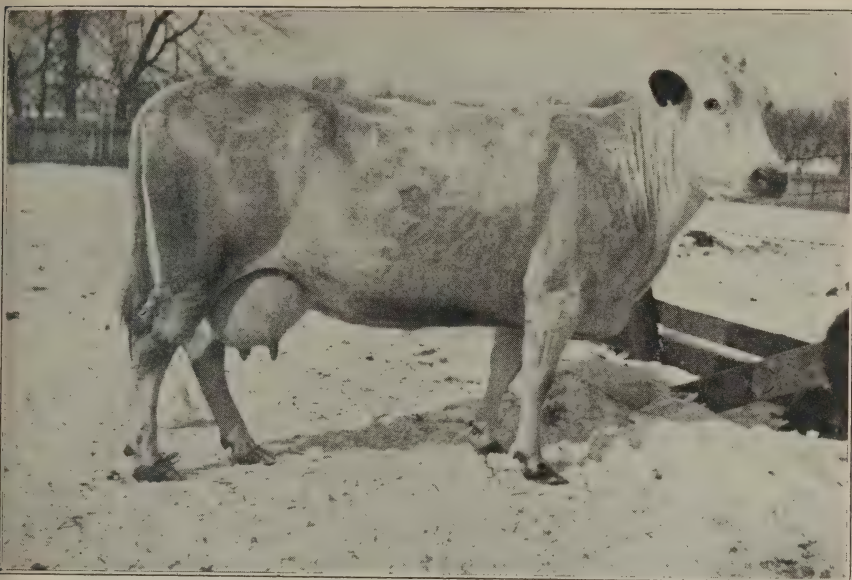
CUT 16. COW NO. 95, HERD D, GAVE IN ONE YEAR 7,615 LB. MILK;
AVERAGE TEST, 4.85%; 430 LB. BUTTER; NET PROFIT, \$42.85.



CUT 17. COW NO. 337, HERD D, GAVE IN ONE YEAR 3,443 LB. MILK;
AVERAGE TEST, 4.46%; 179 LB. BUTTER; NET PROFIT, \$2.52.



CUT 18. COW NO. 263, HERD D, GAVE IN ONE YEAR 4,887 LB. MILK;
AVERAGE TEST, 4.04%; 230 LB. BUTTER; NET PROFIT, \$18.99.



CUT 19. COW No. 40, HERD D, GAVE IN ONE YEAR 6,575 LB. MILK;
AVERAGE TEST, 3.23%; 248 LB. BUTTER; NET PROFIT, \$17.09.

Cow No. 44 charged the most to make butter fat. She charged 22.4 cents to make one pound of butter fat and \$1.03 to make 100 pounds of milk.

The average cost to produce one pound of butter fat was 12.3 cents and 54.9 cents to produce 100 pounds of milk.

Cow No. 147 gave a profit of \$57.22 and cow No. 44 charged 18 cents for her board.

The average profit of each cow in the herd was \$26.64. While the average profit is very good, it would, perhaps, have been better if the owner could have personally looked after his cows. The cows were cared for entirely by hired help.

TABLE 8.—SHOWING PROFIT OR LOSS FOR EACH COW IN HERD "D" FOR ONE YEAR.

GROUP 1.—KEPT AT A LOSS.

No. of cow.	Milk, lb.	Fat, %	Fat, lb.	Lb. of but- ter.	Gross returns.	Cost of feed.	Profit or loss.
44	3,399	4.58	155	181	\$34.85	\$35.03	\$0.18

TABLE 8—Continued.

GROUP 2.—KEPT AT A SMALL PROFIT.

No. of cow.	Milk, lb.	Fat, %	Fat, lb.	Lb. of but- ter.	Gross returns.	Cost of feed.	Profit or loss.
337	3,443	4.46	153	179	\$35.29	\$32.77	\$2.52
324	3,364	4.06	136	159	33.15	29.12	4.03
308	4,617	3.83	177	206	40.17	33.80	6.37
323	4,069	4.15	169	197	40.67	33.92	6.75

GROUP 3.—KEPT AT A FAIR PROFIT.

22	3,187	4.35	138	161	\$29.46	\$19.07	\$10.39
227	4,389	4.40	193	225	40.47	29.22	11.25
272	5,266	3.61	190	222	44.30	32.67	11.63
310	3,777	4.99	188	220	41.86	30.00	11.86
264	4,823	4.07	196	229	46.03	33.50	12.53
99	4,700	4.72	222	259	46.76	32.16	14.60

GROUP 4.—KEPT AT A VERY FAIR PROFIT.

138	5,449	3.99	217	253	\$49.41	\$34.09	\$15.32
40	6,575	3.23	212	248	45.83	28.74	17.09
240	5,257	4.05	213	248	50.07	32.09	17.98
325	5,446	4.30	234	273	52.73	33.94	18.79
263	4,887	4.04	197	230	41.90	22.91	18.99
336	4,796	5.00	239	279	54.11	34.88	19.23
20	4,958	4.51	223	261	51.70	32.13	19.57
13	4,462	5.26	235	274	55.03	33.88	21.15
180	5,505	4.19	230	269	50.14	28.53	21.61
326	5,285	4.79	253	295	57.64	34.07	23.57
335	5,414	4.36	236	275	56.54	32.70	23.84

GROUP 5.—KEPT AT A GOOD PROFIT.

161	5,731	4.70	269	314	\$57.00	\$31.65	\$25.35
309	7,979	3.75	299	349	67.06	41.59	25.47
112	5,481	4.57	250	292	54.63	27.62	27.01
70	6,732	4.34	292	341	63.83	35.95	27.88
190	5,477	5.60	306	357	69.31	39.44	29.87
210	5,201	5.07	263	307	61.90	32.03	29.87
114	6,407	4.00	256	299	59.74	29.02	30.72
38	7,199	4.36	313	366	69.15	37.61	31.54
199	6,132	4.75	291	340	64.04	32.50	31.54
80	5,551	5.14	285	332	65.86	33.94	31.92
87	5,500	4.85	266	311	59.40	27.27	32.13

GROUP 6.—KEPT AT A VERY GOOD PROFIT.

113	5,577	4.99	278	324	\$58.01	\$24.80	\$33.21
109	6,286	4.46	280	327	61.19	25.23	35.96
46	6,549	4.62	302	353	71.29	35.07	36.22
247	6,581	4.76	313	366	69.10	31.68	37.42
95	7,615	4.85	369	430	79.30	36.45	42.85
249	6,811	4.79	326	380	74.20	29.27	44.93

TABLE 8—Continued.

GROUP 7.—KEPT AT AN EXCELLENT PROFIT.

No. of cow.	Milk, lb.	Fat, %	Fat, lb.	Lb. of but- ter.	Gross returns.	Cost of feed.	Profit or loss.
283	10,151	3.68	374	436	\$87.13	\$41.77	\$45.36
129	8,949	4.52	404	472	87.33	40.44	46.89
206	7,130	4.71	336	392	78.30	31.27	47.03
262	9,272	4.01	372	434	84.78	37.74	47.04
102	6,501	5.46	355	414	82.20	34.88	47.32
317	10,059	3.79	381	445	86.95	38.01	48.94
184	7,997	4.77	382	445	83.77	34.35	49.42
147	7,890	4.70	371	432	85.24	28.02	57.22

TABLE 9.—RECORD OF EACH COW IN HERD "D" FOR ONE YEAR.

GROUP 1.—COWS PRODUCING LESS THAN 200 LB. OF BUTTER FAT.

No. of cow.	Age, yr.	Breed.	Date of calving.	Milk, lb.	Fat, %	Fat, lb.	Lb. of but- ter.	Days in milk.
324	...	...	10-15-01	3,364	4.06	136	159	230
22	10	Native ...	3- 7-02	3,187	4.35	138	161	225
337	3	" ...	11- 1-01	3,443	4.46	153	179	304
44	8	Gr. Jersey	3- 1-01	3,399	4.58	155	181	365
323	...	...	10-29-01	4,069	4.15	169	197	245
308	...	...	8-15-01	4,617	3.83	177	206	320
310	4	Native ...	7-21-02	3,777	4.99	188	220	330
272	...	...	8-11-02	4,389	3.61	190	222	350
227	7	Gr. Holst.	5-28-02	5,266	4.40	193	225	274
264	7	Native ...	10- 6-01	4,823	4.07	196	229	303
263	7	Gr. Holst.	4-13-02	4,887	4.04	197	230	218

GROUP 2.—COWS PRODUCING LESS THAN 225 LB. OF BUTTER FAT.

40	9	Native ...	3-23-02	6,575	3.23	212	248	274
240	5	Gr. Holst.	12- 1-01	5,257	4.05	213	248	323
138	6	Gr. S. H..	8-24-01	5,449	3.99	217	253	275
99	7	Native ...	5- 1-02	4,700	4.72	222	259	304
20	5	Gr. S. H..	11-15-01	4,958	4.51	223	261	270

GROUP 3.—COWS PRODUCING LESS THAN 275 LB. OF BUTTER FAT.

180	...	...	3-16-02	5,505	4.19	230	269	267
325	5	Native ...	4-13-02	5,446	4.30	234	273	300
13	9	Jersey....	12- 1-01	4,462	5.26	235	274	302
335	8	Native ...	10-27-02	5,414	4.36	236	275	305
336	...	...	11- 1-01	4,796	5.00	239	279	340
112	10	Gr. Jersey	3-23-02	5,481	4.57	250	292	262
326	7	Native ...	10- 6-01	5,285	4.79	253	295	335
114	10	" ...	1- 5-02	6,407	4.00	256	299	275
210	10	" ...	12- 8-01	5,201	5.07	263	307	305
87	9	" ...	2-23-02	5,500	4.85	266	311	253
161	7	Gr. Jersey	4-13-02	5,731	4.70	269	314	300

TABLE 9—Continued.

GROUP 4.—COWS PRODUCING LESS THAN 325 LB. OF BUTTER FAT.

No. of cow.	Age, yr.	Breed.	Date of calving.	Milk, lb.	Fat, %	Fat, lb.	Lb. of but- ter.	Days in milk
113	9	Native...	3-23-02	5,577	4.99	278	324	295
109	9	"	3-23-02	6,286	4.46	280	327	260
80			11-24-01	5,551	5.14	285	332	309
199	8	Gr. Jersey	3-13-02	6,132	4.75	291	340	309
70	11	Native...	6- 2-02	6,732	4.34	292	341	330
309			7-21-01	7,979	3.75	299	349	365
46	11	Native ...	11- 3-01	6,549	4.62	302	353	302
190	11	Gr. Jersey	6-20-01	5,477	5.60	306	357	365
247	10	Native ...	3-25-02	6,581	4.76	313	366	274
38	10	Gr. Jersey	8- 4-02	7,199	4.36	313	366	265

GROUP 5.—COWS PRODUCING LESS THAN 405 LB. OF BUTTER FAT.

249	5	Native ...	1-19-02	6,811	4.79	326	380	211
206	9	"	10-20-01	7,130	4.71	336	392	350
102	7	Gr. Jersey	11-17-01	6,501	5.46	355	414	300
95	6	Native ...	6-12-01	7,615	4.85	369	430	300
147	8	"	12- 1-01	7,890	4.70	371	432	275
262	8	"	10- 6-01	9,272	4.01	372	434	330
283	8	Gr. Holst.	12- 1-01	10,151	3.68	374	436	316
317	5	Holstein .	9-22-01	10,059	3.79	381	445	365
184	10	Gr. Jersey	3- 9-02	7,997	4.77	382	445	335
129	10	Gr. Holst.	11-15-02	8,949	4.52	404	472	325

REPORT OF HERD "E."

This was a small dairy of seven cows, but each one proved herself to be a profitable animal. The herd consisted of grade Ayrshires, natives, and one grade Jersey; the average weight was 950 pounds. The cows were well fed and cared for during the test, and at the end of the year they were in good healthy condition. No caked udders, abortions, or other mishaps came to this herd during the year and no cows were sold, for every one in the herd gave the owner a good profit. Nearly all the cows came fresh the last of September and the first of October, and went dry in August. It was a winter dairy.

In October and November the cows received five pounds of bran, five pounds of corn meal, corn stover, and some pasture.

In December and to January 15 they received the following:



CUT 20. JENNIE, HERD E, GAVE IN ONE YEAR 4,449 LB. MILK;
AVERAGE TEST, 5.01%; 260 LB. BUTTER; NET PROFIT, \$35.17.

RATION 12.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Grano-gluten	2.5	2.35	.667	.970	.305	2.2c
Bran	6.0	5.31	.774	2.406	.204	5.4c
Corn and cob meal	4.0	3.40	.176	2.400	.116	4.0c
Millet	5.0	4.40	.160	2.425	.050	2.5c
Stover.....	10.0	5.95	.170	3.240	.070	2.0c
Total nutrients		21.41	1.947	11.441	.745	16.1c

This is not only a balanced ration but it contains a variety of food stuffs and is palatable. Palatability should always be considered in making up a ration for a dairy cow.

From January 15 to March 1 the cows received the following ration: Six pounds of bran, three pounds of grano-gluten, five pounds of timothy hay, and all the corn stover they would eat up clean.

In March and to April the 10th, they received 2.5 pounds of bran, 2.5 pounds of grano-gluten, five pounds timothy hay, and corn stover *ad libitum*.

The first part of April the cows were turned out to rye pasture, and about the 15th of May were turned to blue-grass pasture. The herd was given no grain from April 10 to the completion of the year's work. It might be said that the rye pasture was plowed up and



CUT 21. PET HERD E, GAVE IN ONE YEAR 7,488 LB. MILK;
AVERAGE TEST, 4.56%; 398 LB. BUTTER; NET PROFIT, \$48.07.

planted to corn—in other words, this farmer had a good pasture for a month by simply sowing his intended corn ground to rye in the fall. The cows liked the rye pasture so well that they cared nothing for grain when they were grazing in this field.

YEARLY RECORD OF BEST AND POOREST. COW IN HERD "E," AND AVERAGE FOR
ENTIRE HERD.

	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
Best cow, Brindle.....	7,828	4.41	345	403
Poorest cow, Star	5,398	3.89	210	245
Average record of entire herd	6,474	4.19	271	317

Brindle charged 39.1 cents to make 100 pounds of milk, and 8.8 cents to make one pound of butter fat.

Star charged 54.4 cents to make 100 pounds of milk, and 13.9 cents to make one pound of butter fat.

The average cost of production was 43.8 cents to make 100 pounds of milk, and 10.4 cents to make one pound of butter fat.

Brindle gave the largest profit, which was \$49.97, and Star the least, which was \$20.54.

The average profit for each cow in the dairy was \$35.80.

There were no unprofitable cows in this herd, for the owner has always given considerable attention to the selection of his dairy animals.

TABLE 10.—SHOWING PROFIT FOR EACH COW IN HERD "E" FOR ONE YEAR.

Name of cow.	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.	Gross returns.	Cost of feed.	Net profit.
Star.....	5,398.4	3.89	210.42	245.49	\$49.91	\$29.37	\$20.54
Red Ellis.....	5,707.3	4.09	233.89	272.87	55.23	28.48	26.75
Line Back.....	6,552.9	4.08	267.50	312.08	65.54	30.66	34.88
Jennie.....	4,449.9	5.01	223.30	260.51	54.66	19.49	35.17
Blacky.....	7,896.7	3.55	280.44	327.18	65.94	30.69	35.25
Pet.....	7,488.9	4.56	341.95	398.94	77.44	29.37	48.07
Brindle.....	7,828.7	4.41	345.73	403.35	80.63	30.66	49.97

TABLE 11.—RECORD OF EACH COW IN HERD "E" FOR ONE YEAR.

Name of cow.	Age, yr.	Breed.	Date of calving.	Milk, lb.	Fat, %	Fat, lb.	Lb. of but- ter.	Days in milk.
Star.....	3.5	H. & J.	10-15-02	5,398	3.89	210	245	320
Jennie.....	6	Jersey.....	1- 8-02	4,449	5.01	223	260	245
Red Ellis...	6	J. & S. H. ...	9-20-01	5,707	4.09	233	272	315
Line Back..	5	Native.....	9-20-01	6,552	4.08	267	312	275
Blacky.....	4	".....	9-15-01	7,896	3.55	280	327	280
Pet.....	8	Gr. Ayrshire.	9-25-01	7,488	4.56	341	398	330
Brindle....	9	".....	9-28-01	7,828	4.41	345	403	327

REPORT OF HERD "F."

There were fourteen full-blood Holstein cows in this herd that were tested; their average weight was about 1,050 pounds. A few of the cows that did not enter the test were disposed of before the end of the year for they had already proved themselves to be inferior and unprofitable animals. Less than half the dairy was matured cows. The herd was well cared for, but they did not receive a very large grain ration during the year, for the owner thought it would be more profitable to make less milk and butter fat than it would be to buy feed for his cows; the price of all kinds of grain being so very high last year.

The herd was kept in comfortable quarters, was in healthy condition during the test, and did a good year's work considering the grain that was given them.

The first period of the test the cows received a good ration which contained the following food stuffs:



CUT 22. CHECK, HERD F, GAVE IN ONE YEAR 6,812 LB. MILK;
AVERAGE TEST, 3.16%; 251 LB. BUTTER; NET PROFIT, \$19.30.

RATION 13.

Food stuffs.	Lb.	Dry matter.	Protein.	Carbohydrates.	Fat.	Cost.
Bran	4	3.54	.516	1.604	.136	3.6c
Oats	4	3.56	.368	1.892	.168	4.4c
Clover hay	5*	4.23	.340	1.790	.085	2.5c
Stover.....	10	5.95	.170	3.240	.070	2.0c
Silage	35	7.31	.315	3.955	.245	3.5c
Total nutrients.....		24.59	1.709	12.481	.704	16.0c

This is a very good ration for it contains a variety of feeds and enough nutrients for cows giving good flows of milk. The dry grains and dry roughage are mixed and in about the right proportion to the amount of corn silage. It is, perhaps, a little deficient in protein for heavy milking cows.

The second period of the test the cows received no grain. The ration consisted of thirty-five pounds of corn silage, five pounds clover hay, and all the corn stover they would eat. Each cow shrank considerably in milk flow, and the average percent of fat was less during this period. The cows received the following ration from the first of February until they were turned out to grass:



CUT 23. MAID, HERD F, GAVE IN ONE YEAR 5,979 LB. MILK;
AVERAGE TEST, 3.34%; 233 LB. BUTTER; NET PROFIT, \$17.95.

RATION 14.

Food stuffs.	Lb.	Dry matter.	Pro- tein.	Carbohy- drates.	Fat.	Cost.
Grano-gluten	2	1.88	.534	.776	.248	1.8c
Silage	35	7.31	.315	3.955	.245	3.5c
Clover hay	5	4.23	.340	1.790	.085	2.5c
Corn stover	10	5.95	.170	3.240	.070	2.0c
Total nutrients.....		19.37	1.359	9.761	.648	9.8c
Oat straw, <i>ad libitum</i> .						

This is a better ration than the one that was fed during the second period of the test, and there was an increase in milk flow and an increase in percent of fat. The cows were turned out to pasture about June 19. The owner did not have enough pasturage to feed his herd entirely so the ration was supplemented with thirty pounds of corn silage a day. This ration was continued to the completion of the test. It is the belief of the owner that the cows would have given a larger profit if he had fed them more grain. While the above facts do not demonstrate that the herd would have been more profitable with better feeding, yet, judging by the individuality of each of the cows, better results might have been expected if more grain had been fed. The cows were certainly capable

of giving more milk and butter fat than the records show, if they had received a better ration.

YEARLY RECORD OF BEST AND POOREST COW IN HERD "F," AND AVERAGE FOR ENTIRE HERD.

	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
Best cow, Princess	7,817	3.35	262	305
Poorest cow, Mittie	3,461	3.19	110	128
Average record of entire herd	5,846	3.32	194	227

Princess, the best cow, charged 33.5 cents to produce 100 pounds of milk, and 10 cents to make one pound of butter fat; and Mittie charged 62.3 cents to produce 100 pounds of milk, and 19.5 cents to make one pound of butter fat.

The average cost of production was 42.9 cents to yield 100 pounds of milk, and 12.9 cents to make one pound of butter fat.

Princess gave a profit of \$32.63 and Mittie a profit of \$2.75.

The average profit for each cow in the dairy was \$18.58.

TABLE 12.—SHOWING PROFIT FOR EACH COW IN HERD "F" FOR ONE YEAR.

GROUP 1.—KEPT AT A PROFIT.							
Name of cow.	Milk, lb.	Fat, %	Fat, lb.	Lb. of butter.	Gross returns.	Cost of feed.	Net profit.
Mittie	3,461.8	3.19	110.54	128.96	\$24.33	\$21.58	\$2.75
Lady	4,386.4	3.39	149.05	173.89	34.41	22.66	11.75
Joe's Bride	5,136.7	3.00	154.32	180.04	32.31	20.47	11.84
Loma	5,677.1	3.14	178.44	208.18	40.96	27.85	13.11
Bell	5,050.2	3.61	182.56	212.98	38.89	23.94	14.95
Maid	5,979.1	3.34	200.12	233.47	44.22	26.27	17.95

GROUP 2.—KEPT AT A FAIR PROFIT.

	Milk, lb.	Fat, %	Fat, lb.	Lb. of butter.	Gross returns.	Cost of feed.	Net profit.
Mutual	5,586.5	3.25	181.82	212.12	\$41.07	\$22.11	\$18.96
Check	6,812.6	3.16	215.79	251.75	50.22	30.92	19.30
Maud	5,426.9	3.39	184.36	215.03	42.54	22.66	19.88
Zipsy	6,219.2	3.53	219.73	256.35	49.03	26.57	22.46
Echo	6,039.6	3.66	221.16	258.02	50.03	27.52	22.51

GROUP 3.—KEPT AT A GOOD PROFIT.

	Milk, lb.	Fat, %	Fat, lb.	Lb. of butter.	Gross returns.	Cost of feed.	Net profit.
Zur.	6,610.0	3.29	218.01	254.34	\$49.58	\$25.55	\$24.03
Alfrida.	7,641.5	3.22	246.10	287.11	55.55	27.52	28.03
Princess.	7,817.4	3.35	262.28	305.99	58.88	26.25	32.63

TABLE 13.—RECORD OF EACH COW IN HERD "F" FOR ONE YEAR.

GROUP 1.—COWS YIELDING LESS THAN 180 LB. OF BUTTER FAT.

Name of cow.	Age, yr.	Breed.	Date of calving.	Milk, lb.	Fat, %	Fat, lb.	Lb. of but- ter.	Days in milk.
Mittie.....	3	Holstein .	7-17-02	3,461	3.19	110	128	260
Lady.....	4	"	12- 1-01	4,386	3.39	149	173	300
Joe's Bride.....	9	"	4- 5-02	5,136	3.00	154	180	275
Loma.....	12	"	2-13-02	5,677	3.14	178	208	235

GROUP 2.—COWS YIELDING LESS THAN 205 LB. OF BUTTER FAT.

Mutual.....	2	Holstein .	11-18-01	5,586	3.25	181	212	315
Belle.....	3	"	5-28-02	5,050	3.61	182	212	302
Maud.....	3	"	12- 1-01	5,426	3.39	184	215	300
Maid.....	3	"	10- 9-01	5,979	3.34	200	233	330

GROUP 3.—COWS YIELDING LESS THAN 275 LB. OF BUTTER FAT.

Check.....	15	Holstein .	1-23-02	6,812	3.16	215	251	252
Zur.....	2	"	1-31-01	6,610	3.29	218	254	305
Zipsy.....	3	"	10-13-01	6,219	3.53	219	256	335
Echo.....	4	"	10-11-01	6,039	3.66	221	258	334
Alfrida.....	7	"	10-14-01	7,641	3.22	246	287	336
Princess.....	4	"	8-26-01	7,817	3.35	262	305	330

REPORT OF HERD "G."

There were only five cows in this herd at the beginning of the test and two of them were sold three months after the work began. The strange thing about the selling of these animals was that they were good cows, for they had averaged $7\frac{1}{2}$ pounds of butter fat a week up to the time that they were disposed of. The herd was not well fed or cared for, but did a very fair year's work, notwithstanding. The cows were not kept in a comfortable barn, or one that was well cleaned. The dairy with this man was, so to speak, a sort of necessary evil.

The amount of grain and roughage that each cow consumed during the year was not kept, so there is no feed account reported.

TABLE 14.—RECORD OF EACH COW IN HERD "G" FOR ONE YEAR.

Name of cow.	Breed.	Milk, lb.	Fat, %	Fat, lb.	Lb. of butter.	Days in milk.
Jersey.....	Gr. Jersey.....	3,644	3.96	144	168	275
Mollie.....	Native.....	3,930	3.94	155	180	210
Lucy.....	".....	7,021	3.94	277	323	280

REPORT OF HERD "H."

This herd consisted of eight native cows whose average weight was about 1,000 pounds. The cows were very ordinary animals and they did a very ordinary year's work. The most of them calved in March, and were dry by the first of November, the owner not trying to make milk in winter. The barn in which these cows were kept was very poor, being cold and poorly cared for. The stock was often exposed to cold, rain, and snowstorms, and the frozen snow and ice was often removed with brooms from the animals' backs.

In March and April the cows received a small amount of bran and corn meal and about one pound of oil meal a day, with clover hay and corn stover. By May 15 the cows were turned into a pasture which was not very good, the greater portion of it being woods. They received in connection with pasturage about two pounds of bran a day, but this was not enough grain when the kind of pasture is considered. The latter part of July the cows were changed to a good clover pasture.

TABLE 15.—SHOWING RECORD OF TWO COWS EVERY SEVENTH WEEK DURING THEIR PERIOD OF LACTATION.

FANNY.				
Week ending.	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
March 31.....	192.4	3.2	6.16	7.18
May 19.....	142.4	4.3	6.12	7.14
July 7.....	84.3	4.0	3.37	3.93
August 25.....	70	6.9	.48	.56

LILY.				
Week ending.	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
May 19.....	171	3.9	6.67	7.78
July 17.....	99	3.5	3.47	4.04
August 25.....	123.9	3.6	4.46	5.20
October 27.....	75.2	4.1	3.08	3.59

These tables are good examples of the milk and butter fat yield of all the cows at different times during the test. They clearly show that the cows were not persistent milkers. The individuality of the cows, the poor care, and the poor feeding which they received, undoubtedly caused the rapid decline in milk and butter fat production from one period to the next and their short period of lactation.

The cows gave more milk and butter fat in the August test than they did in July. This was probably due to the fact that the cows were taken from a poor wood pasture the last of July and put into a good clover pasture.

YEARLY RECORD OF BEST AND POOREST COW IN HERD "H," AND AVERAGE FOR ENTIRE HERD.

	Milk, lb.	Fat, %	Fat, lb.	Butter, lb.
Best cow, Jessie	5,420	4.08	221	258
Poorest cow, Fanny	2,398	3.92	94	109
Average record of entire herd	3,852	4.02	155	180

TABLE 16.—RECORD OF EACH COW IN HERD "H" FOR ONE YEAR.

Name of cow.	Age, yr.	Breed.	Date of calving.	Milk, lb.	Fat, %	Fat, lb.	Lb. of butter.	Days in milk.
Fanny.....	.....	Native...	3-20-02	2,398	3.92	94	109	195
Lucy.....	2	"...	3-31-02	2,843	4.31	122	143	230
Bess.....	4	"...	2-20-02	3,895	3.70	144	168	240
Lily.....	2	"...	3-25-02	3,937	3.80	149	174	225
Liza.....	5	"...	3-13-02	3,980	4.07	162	189	230
Reddie.....	6	"...	1-21-02	3,848	4.23	163	190	235
Belle.....	7	"...	3-23-02	4,498	4.07	183	213	215
Jessie.....	5	"...	3-22-02	5,420	4.08	221	258	216

It is perhaps well to compare the performance of eight of the poorest cows as well as eight of the best cows kept in different herds, and also compare the average production and profit of each herd tested. This is done to show the great differences, even among the poorest and best cows, and also the difference in production and profit between herds of cows kept upon the farms of Illinois.

TABLE 17.—COMPARING THE PERFORMANCE OF THE POOREST COWS KEPT IN DIFFERENT HERDS.

Cow.	Herd.	Milk, lb.	Fat, %	Lb. of butter.	Net profit or loss.	Cost of 100 lb. of milk.	Cost of 1 lb. of fat.
No. 37	"A"	1,482	3.97	68	\$-17.83	\$2.07	52.2c
Harrison.....	"C"	2,721	3.96	126	— 1.27	.97	24.6c
Red Bird.....	"B"	4,974	3.04	176	— 1.28	.70	23.2c
No. 44	"D"	3,399	4.58	181	— .18	1.03	22.4c
Mittie.....	"F"	3,461	3.19	128	2.75	.62	19.5c
Star.....	"E"	5,398	3.89	245	20.54	.54	13.9c
Jersey.....	"G"	3,644	3.96	168			
Fanny.....	"H"	2,398	3.92	109			

* This is estimated on the basis that it took 140 lb. of butter fat to pay for feed.

TABLE 18.—COMPARING THE PERFORMANCE OF THE BEST COWS KEPT IN DIFFERENT HERDS.

Cow.	Herd.	Milk, lb.	Fat, %	Lb. of butter.	Net profit.	Cost of 100 lb. of milk.	Cost of 1 lb. of fat.
Jersey	"C"	5,498	4.48	287	\$34.77	29.7c	6.6c
No. 147	"D"	7,890	4.70	432	57.22	35.5c	7.5c
Brindle	"E"	7,828	4.41	403	49.97	39.1c	8.8c
Princess	"F"	7,817	3.35	305	32.63	33.5c	10.0c
Spotty No.1	"B"	7,711	3.20	288	25.32	40.7c	12.6c
No. 15	"A"	6,145	3.63	260	*18.40	50.1c	13.7c
Lucy	"G"	7,021	3.94	323			
Jessie	"H"	5,420	4.08	258			

* This is estimated on the basis that it took 140 lb. of butter fat to pay for feed.

TABLE 19.—COMPARING THE AVERAGE PERFORMANCE OF ALL THE COWS IN EACH OF THE HERDS TESTED.

Herd.	Milk, lb.	Fat, %	Lb. of butter.	Net profit or loss.	Cost of 100 lb. of milk.	Cost of 1 lb. of fat.
"A"	3,361	3.55	139	\$-4.54	92.5c	25.8c
"B"	5,360	3.52	220	12.12	57.0c	16.1c
"C"	4,942	3.90	224	16.22	55.5c	14.2c
"F"	5,846	3.32	227	18.58	42.9c	12.9c
"D"	5,911	4.45	306	26.64	54.9c	12.3c
"E"	6,474	4.19	317	35.80	43.8c	10.4c
"G"	4,865	3.95	224			
"H"	3,852	4.02	180			

TABLE 20.—COMPARING THE RESULTS FROM THE SIX MOST PROFITABLE COWS IN HERD "D" WITH THE RESULTS FROM FIVE OTHER HERDS.

Herd.	No. of cows in herd.	Lb. milk.	Lb. butter.	Total profit.	Total loss.
"D"	6	50,669	2,644	\$296.97	.....
"A"	28	94,126	3,899	.....	\$127.12
"B"	20	107,217	4,409	242.41	.....
"C"	17	84,014	3,823	275.90	.....
"E"	7	45,322	2,220	250.63	.....
"F"	14	81,845	3,178	260.15	.....

This table simply shows that a few good cows will yield a greater profit than large herds of unselected animals. It was found in herd "D," that fifteen of the best cows gave a profit of \$651.94 while the other thirty-two cows gave a profit of only \$600.24, or, the fifteen cows gave the owner \$51.70 more profit than the other thirty-two cows. It shows very clearly that it is far better to keep a few very good cows than large herds of our ordinary cows. The work is less and profit larger.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

URBANA, JUNE, 1903.



BULLETIN No. 86.

CLIMATE OF ILLINOIS.

By J. G. MOSIER, B. S., CHIEF ASSISTANT IN SOIL PHYSICS.

This state lies with its northern boundary $2\frac{1}{2}^{\circ}$ south of the center of the north temperate zone, while the southern extremity is only $13\frac{1}{2}^{\circ}$ from the torrid zone. It extends over $5\frac{1}{2}^{\circ}$ of latitude, or about 380 miles. It is situated mostly in the belt of hot summers and cold winters, but in the southern part the winters are temperate. The altitude of the state above sea varies between 320 feet in the extreme southern part to 1,257 feet in Jo Daviess County, the highest point in the state. The Ozark Ridge, extending east and west across the southern end, reaches a height of 1,046 feet in the northwest of Pope County. This range of altitude is too small to affect the climate to any marked extent, although the Ozark Ridge does seem to exert some influence over the rainfall.

The state lies entirely within the belt of prevailing westerly winds with its accompanying cyclones and anticyclones. To these "lows" and "highs," as they are commonly designated by the weather forecaster, is due the peculiar climate of the state. Our weather changes are almost entirely caused by the passage of these across the country, and their importance requires more than a passing notice here.

CYCLONES, OR LOWS; ANTICYCLONES, OR HIGHS.

A cyclone, or "low," is an area having an atmospheric pressure lower than the normal, due to the rising of air in that locality. Throughout this area the top of the column of mercury in the barometer (used in

measuring the pressure of the air) is lower than normal, hence the word "low." A "high" is, of course, an area where the atmospheric pressure is higher than normal and the term anticyclone is sometimes used to mean the same thing.

Low pressure areas are very large whirlwinds from a few hundred to as much as two thousand miles in diameter. These lows, or cyclones, are to be distinguished from the small, very violent whirlwinds or tornadoes that are so much dreaded. The term cyclone is very frequently erroneously applied to tornadoes but in the cyclone proper the wind rarely attains a velocity sufficient to do much damage. The usual movement of cyclones is in an easterly direction, at from twenty to thirty miles an hour. During the cooler season of the year they pass more rapidly and are better defined than in summer.

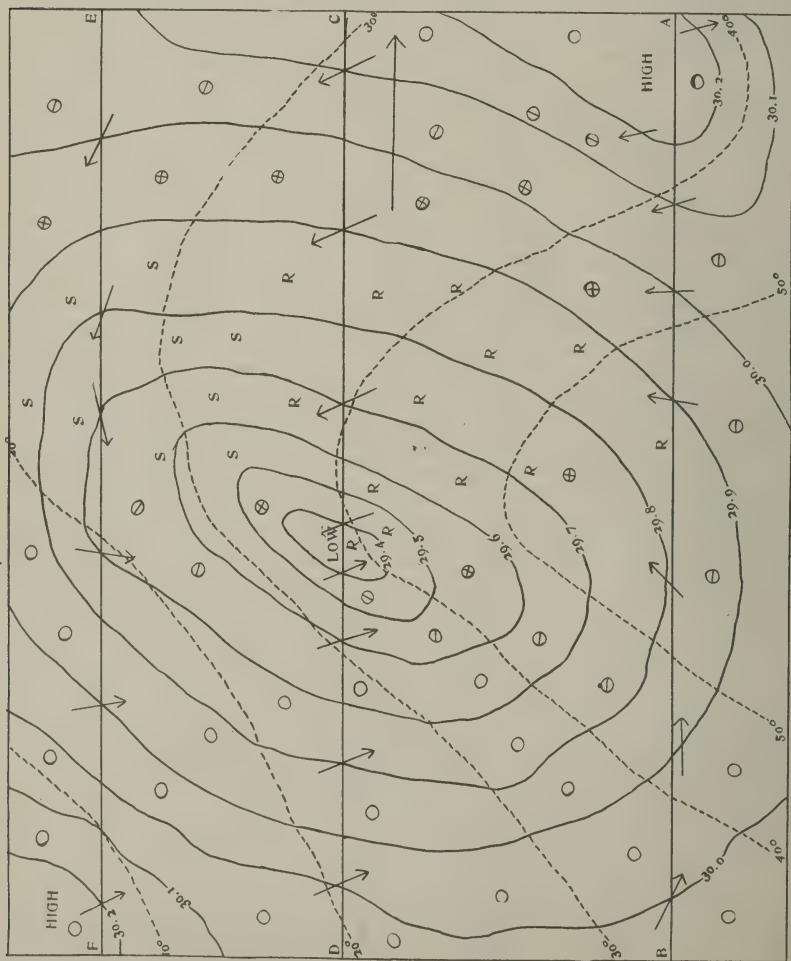


PLATE I. DIAGRAM OF A WINTER CYCLONE, SHOWING PROBABLE CHANGES IN WIND, TEMPERATURE, BAROMETRIC PRESSURE, AND WEATHER CONDITIONS.

The approach of a cyclone is usually indicated by the changing of the wind to a southerly or an easterly direction, by the appearance of white, stringy, or fibrous clouds, or by a general haziness that produces a halo or circle around the sun or moon.

Plate I is a diagram of a "low" as it is represented on weather maps. The large arrow represents the direction of movement. The heavy curved lines are isobars and are drawn through places having the same atmospheric pressure. The meaning of the term "low" may be readily seen from this. The dotted lines are isotherms, or lines drawn through places having the same temperature. Small arrows point in the direction toward which the wind is blowing. The circles and letters indicate the condition of the weather; as, $\circ$, clear; $\ominus$, partly cloudy; $\oplus$, cloudy; R, rain; S, snow.

One of the most important and noticeable changes that occurs during the passage of a cyclone is the shifting of the wind with its accompanying change in temperature. Let us notice some of the changes that take place as the different parts of the cyclone pass over different places. Let us assume a place, so situated that the southern part of the storm passes over it, along the line A B. (See Plate I.)

Since a cyclone is a whirling storm the wind will not blow *directly* in toward the center of the low, but *spirally*, as could be shown by producing one of the small arrows so as to have it approach the center forming a spiral. At A in the "high," the wind will blow from the north, but as the storm approaches it will shift to the south or southeast, and at the same time the temperature will begin to rise. As the storm passes eastward the wind will change to southwest, to west, and then to northwest, and the temperature will become lower until 25° is reached at B. If the storm pass over a place along the line C D, the wind will blow from the southeast till the center of the storm is reached, when it will suddenly change to the northwest with a lowering of temperature until 20° or lower is reached. If the northern part of the cyclone pass over a place along the line E F, the wind will blow from an easterly direction, but as the center of the storm passes to the south there will be a gradual shifting of the wind to the north and northwest with a lowering of temperature. The easterly winds of this part of the storm are usually accompanied by cold, steady rains in the warmer seasons, and by heavy snows in winter. The rainfall in the southeast part of a cyclone is usually in the form of local showers, frequently very heavy. As a general thing, little rain or snow falls after the center of the low is past and the wind has shifted to the west or northwest. Clearing weather usually follows the passage of the center, and the rear of the storm is marked by cool, clear weather. The directions of the wind given above are greatly modified by the fact that the cyclone frequently comes from the northwest to about the Mississippi Valley and then turns to the northeast.

SOURCES OF DATA.

The data for this bulletin was very largely obtained from the records and publications of the Weather Bureau, and I desire to thank the directors of the stations, and especially the Chief of the Weather Bureau, for so kindly furnishing the data desired. The records for some of the counties are fragmentary, and in many cases short, and eleven have no records; but the records obtained are so well distributed that a good average for the state, districts, and a very large number of counties has been obtained. For counties without records the averages have been obtained by taking the data from surrounding counties. In a few cases records have been taken from stations just outside of the state, as Dubuque, Davenport, and Keokuk, Iowa; Hannibal and St. Louis, Missouri; Paducah, Kentucky; Vincennes and Terre Haute, Indiana; and Beloit, Wisconsin.

DISTRICTS.

For convenience, the state has been divided into three districts, or sections, the northern, central, and southern. The boundary between the northern and central sections is formed by the county lines lying nearest the parallel of $40^{\circ} 40'$, and that between the central and southern sections by the county lines nearest the parallel of 39° .

TABLE 2.—AVERAGE RAINFALL BY YEARS' FOR THE DISTRICTS AND THE STATE—INCHES.

District.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.
Northern	35.15	34.72	27.20	34.85	40.22	38.87	34.92	29.70	37.09	42.64	39.23
Central	32.65	43.17	32.17	43.22	46.67	46.12	43.18	22.85	38.02	48.11	44.91
Southern	30.05	49.51	46.82	48.48	54.03	43.23	43.25	43.08	46.30	36.73	55.68
Av. for state . .	33.32	40.35	32.45	39.23	45.47	41.32	41.07	33.03	39.51	41.94	45.01

District.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.
Northern	40.72	40.07	38.56	28.88	31.36	31.77	31.27	34.09	21.46	41.35	29.90
Central	43.40	39.56	40.93	36.12	33.27	41.51	36.80	32.82	31.09	41.27	39.94
Southern	51.93	47.55	41.34	38.54	34.64	42.13	40.96	48.68	36.10	39.78	41.40
Av. for state . .	45.06	42.32	40.02	34.01	32.71	38.21	35.88	38.33	29.62	40.02	34.11

District	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	Av.
Northern	26.77	28.04	34.76	29.16	41.65	29.03	34.33	22.95	47.22	33.48
Central	28.36	32.75	37.75	37.03	45.29	34.64	35.09	26.19	41.56	38.01
Southern	31.77	34.91	39.23	45.63	53.62	38.91	38.26	30.34	35.03	42.19
Average for state . .	28.33	31.17	36.62	36.48	47.39	33.91	35.70	25.00	41.58	37.39

TABLE I.—ANNUAL RAINFALL IN INCHES BY COUNTIES AND YEARS.

Northern District.																	
1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	
Bureau										50.10	34.40	27.90	36.20	51.50	32.20	36.40	
Cook					50.20	68.60	70.40	50.40	38.30	34.30	36.20	22.40	36.50	31.50	23.00	35.50	
DeKalb	29.10		47.30		26.90	38.50	34.90	33.90	25.00	36.20	36.40	34.80	33.40	39.00	25.10	33.70	
Jo Daviess			47.40	30.50								31.20			24.30		
Kane							42.90					23.20					
Knox							55.70					28.20					
LaSalle		29.50	34.70	47.20	27.80	30.80	38.90	36.70	29.40	36.60	32.80	23.20	33.50	38.00	23.10	34.20	
McHenry															29.48	27.83	
Peoria		26.15	30.47	53.94	30.32	34.05	30.28	48.43	32.26	30.26	37.00	35.75	42.12	42.30	23.67	32.42	
Rock Island											38.03	29.21	34.31	45.82	41.30	32.73	
Stark							Stark				28.90	24.27	34.83	42.30			
Winnebago			45.16	26.51	32.90	44.61					44.82	38.89	26.74	35.31	27.17		
1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	
Boone																	
Bureau	46.10	39.90	35.00	48.00											38.95	28.86	
Cook	29.07	36.41	28.63	38.06	36.48	41.01	41.95	30.71	37.32	44.18	41.34	45.86	34.61	44.37	26.77	29.61	
DeKalb	39.50	54.50		53.20							43.40	51.00	44.76	40.11	27.70	34.10	
Grundy																26.97	
Henderson			29.60	34.50	35.60	46.20	36.80	23.60	29.90	41.20					27.70	33.90	
Henry					42.60	35.70	30.90	38.50	40.10						29.40		
Iroquois															30.32	29.43	
Jo Daviess			30.77	35.12	44.08	38.97	38.76	32.40	40.32	46.10	32.84	39.57	42.89	40.45	34.30	33.31	
Kane									44.49	45.75	43.03	46.21	36.76	39.50	32.46	34.10	
Kendall									43.10	39.10	41.30	38.70	36.20	35.30	25.21	27.37	
Knox															41.26	42.27	
Lake															33.80	29.29	
LaSalle															23.75	30.27	
Lee															40.33		
Livingston															18.90	26.50	
McHenry	33.45	28.36	24.35	34.68	39.57	35.44	32.44	32.32	33.29	47.22	35.36	35.91	34.95	31.24	33.24	26.41	
Marshall															36.86		
Mercer															28.30		
Peoria	38.85	38.58	25.04	39.27	43.06	39.82	31.46	28.97	39.89	41.05	41.39	39.63	41.80	32.40	28.33	27.50	
Putnam	32.40	28.60	26.00	34.00	37.30	33.30	31.90								28.23	28.22	
Rock Island	26.65	19.82	24.36	26.81	35.89						36.60	34.59	38.11	34.35	23.15	31.23	
Stark		31.60	24.39	26.59	34.50	34.44	31.67	24.74	32.16	39.00	37.50					40.50	
Stephenson																	
Whiteside							33.28	36.98	41.18	41.98	38.71	43.04	38.21	29.74	34.31	35.76	
Winnebago			23.90	31.51	42.56	38.06	33.64	30.42	32.07	44.21	36.76	37.09	47.65	44.15	35.47	30.82	

TABLE I.—ANNUAL RAINFALL IN INCHES BY COUNTIES AND YEARS—Continued.

Northern District.															
	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	Aver.
Boone.....	33.80	36.44	31.04	43.21	31.24	33.51	23.16	31.95	24.92	39.63	25.99	33.83	19.28	39.05	32.16
Bureau.....	31.17	38.54	31.74	41.69	26.78	27.05	25.88	34.21	30.98	42.55	29.30	37.64	23.88	50.21	36.72
Carroll.....	31.51	32.77	26.54	36.56	28.66	27.46	22.58	35.54	25.59	32.53	37.18	32.26	17.92	46.50	31.96
Cook.....	28.21	31.84	32.27	45.64	33.05	29.75	23.19	27.36	26.82	39.36	28.43	30.23	25.02	41.95	33.68
DeKalb.....	37.47	.....	.....	.....	.....	.....	.....	41.47	33.66	45.02	30.05	29.83	21.35	48.08	36.25
DuPage.....	.....	.....	.....	36.81	30.16	27.97	35.12	41.47	33.01	34.32	44.83	41.77	31.40	50.00	33.99
Ford.....	35.83	36.07	.....	.....	.....	.....	.....	29.69	31.88	42.05	28.53	41.77	31.40	50.00	33.99
Grundy.....	33.82	34.11	30.12	39.63	32.53	22.54	28.28	37.66	34.97	51.00	42.06	35.72	24.36	48.23	33.59
Henderson.....	.....	.....	.....	24.62	.....	.....	.....	36.36	26.25	49.72	29.89	34.24	23.66	50.60	36.20
Henry.....	36.69	36.74	.....	48.77	30.77	19.35	19.74	32.23	29.18	38.89	26.00	36.33	29.15	50.68	34.02
Jroquois.....	24.25	43.16	27.55	44.45	29.10	29.05	31.86	40.45	32.20	35.75	30.90	33.43	20.39	38.34	34.25
Jo Daviess.....	31.84	32.61	31.09	.....	.....	28.23	26.05	37.38	23.74	44.60	28.87	29.81	22.21	50.90	35.10
Kane.....	.....	.....	.....	41.02	29.82	27.17	39.41	38.07	31.66	40.46	.....	.....	20.07	47.33	32.18
Kankakee.....	28.58	34.71	31.85	33.68	29.79	27.84	28.35	33.21	32.87	52.73	28.93	31.39	18.80	48.50	31.31
Kendall.....	29.96	38.49	31.52	45.87	27.72	29.72	28.35	33.21	32.87	43.62	30.83	34.49	24.93	37.87	35.54
Knox.....	34.27	31.81	35.37	39.56	30.49	22.68	24.24	29.69	31.88	42.05	26.88	33.90	22.36	45.63	30.78
Lake.....	.....	.....	.....	.....	.....	.....	.....	36.70	31.23	38.86	26.83	34.18	25.91	48.23	31.53
LaSalle.....	.....	.....	.....	43.21	29.95	35.49	28.08	29.69	31.88	42.05	26.88	33.90	25.91	48.23	30.49
Lee.....	31.98	32.67	31.57	35.26	31.20	29.12	30.79	38.81	31.69	48.05	31.45	37.12	24.59	39.06	32.70
Livingston.....	24.52	36.44	31.29	.....	.....	.....	.....	34.48	25.90	38.41	22.34	30.98	17.03	49.28	35.71
McHenry.....	30.59	29.64	37.25	35.26	31.20	29.12	24.81	32.93	26.34	38.77	27.01	38.65	22.27	43.16	30.12
Marshall.....	33.47	31.87	42.30	35.26	31.20	29.12	24.81	32.93	26.34	38.77	27.01	38.65	22.27	43.16	30.12
Mercer.....	26.65	24.39	34.97	35.66	31.72	30.99	35.72	36.14	28.33	40.08	30.99	34.64	26.02	48.32	34.71
Ogle.....	35.05	31.42	30.94	35.60	41.78	30.79	38.81	31.69	48.05	31.45	37.12	24.59	24.59	57.05	32.42
Peoria.....	37.61	26.10	31.45	44.15	28.21	18.52	25.96	31.58	24.91	38.68	31.64	30.17	17.33	40.31	32.19
Putnam.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.56
Rock Island.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.61
Stark.....	23.88	41.40	.....	.....	.....	.....	.....	37.36	27.16	44.45	27.13	29.14	23.39	30.43	32.61
Stephenson.....	.....	.....	.....	.....	.....	.....	.....	37.36	27.16	44.45	27.13	29.14	23.39	30.43	32.61
Warren.....	30.83	32.22	33.38	40.64	30.39	27.44	30.38	33.94	25.55	41.39	30.45	37.25	22.07	44.80	34.87
Whiteside.....	.....	.....	.....	.....	.....	.....	.....	34.94	30.93	44.35	26.62	39.78	27.28	56.11	35.05
Will.....	26.97	37.01	30.52	49.93	32.98	26.39	26.87	35.85	28.62	40.21	30.89	39.74	25.12	43.21	35.39
Winnebago.....	.....	.....	.....	.....	.....	.....	.....	31.84	27.32	41.46	29.31	30.87	20.39	47.29	32.65
Woodford.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

* Average from surrounding counties.

Central District.																	
	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.
Brown.....																33.60	34.00
Coles.....																30.80	
Hancock.....			28.70	51.00	44.90		32.50	54.00	30.80	36.10	42.00	39.30	27.60	45.20	47.50	33.70	40.80

[illegible]

TABLE I.—ANNUAL RAINFALL IN INCHES BY COUNTIES AND YEARS—Continued.

Central District.															
	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	Aver.
Hancock.....	26.57	21.65	28.48	37.45	24.13	25.20	29.38	43.41	38.19	50.20	39.28	31.13	23.22	42.88	36.40
Jasper.....							33.77	34.97	36.30	50.55	37.20	34.79	20.58	35.54	*38.97
Jersey.....							30.08	32.66	31.42	45.12	32.94	39.17	29.32	35.46	35.46
Logan.....	34.54	24.07	38.41			29.61	30.08	32.66	31.42	45.12	32.94	39.17	29.32	35.53	33.53
Macon.....						25.95	30.91	35.34	33.67	47.91	30.77	41.32	27.26	43.22	35.71
Macoupin.....			27.64	48.83	37.12	30.51	31.69	41.56	37.81	51.11	37.22	36.66	26.77	43.50	35.39
McDonough.....					31.48	27.19	33.01	35.48	29.19	48.91	36.77	31.76	20.60	43.50	32.60
McLean.....					30.29	27.97	37.30	37.86	33.64	43.71	29.93	26.63	26.63	50.93	34.99
Mason.....					33.01	25.30	32.82	31.31	33.17	45.10	40.21	33.73	23.39	50.93	35.56
Menard.....								32.20	36.86	54.03	40.15	32.77	28.01	43.97	38.70
Montgomery.....								32.26	34.66	44.58	34.35	30.87	21.64	37.66	32.55
Morgan.....								33.43	33.43	33.43	33.43	33.43	33.43	37.98	34.09
Moultrie.....								34.33	34.33	34.33	34.33	34.33	34.33	37.98	34.09
Piatt.....							34.33	48.25	56.16	57.20	28.44	36.86	24.23	41.62	36.20
Pike.....	38.70	27.92	25.82	42.09	31.94	22.78	38.76	38.83	38.30	50.38	38.97	31.36	21.91	38.87	34.59
Sangamon.....	33.31	28.68	32.27	42.47	34.73	28.34	35.01	32.66	37.38	52.29	38.14	31.15	23.30	36.71	36.94
Schuyler.....			30.35	41.16	37.51	34.09	38.17	37.38	37.38	54.37	39.09	32.63	22.94	43.31	37.98
Scott.....										54.37	39.09	32.63	22.94	47.84	35.43
Shelby.....	40.29														37.31
Tazewell.....	36.08	26.33	41.70	41.03	36.76	27.63	34.07	34.48	27.53	46.33	29.63	30.74	18.86	41.67	34.89
Vermilion.....				37.02					31.55	46.33	29.63	30.74	18.86	41.67	34.45

* Average from surrounding counties.
† Record previous to 1855 for Menard county: 1843, 40.90 inches; 1844, 48.20; 1845, 43.20; 1846, 45.00; 1847, 32.50; 1848, 44.20; 1849, 38.50; 1850, 40.70; 1851 46.80; 1852, 38.40; 1853, 34.80; 1854, 31.10.

Southern District.																	
	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.
Clay.....																	
St. Clair.....	50.50	42.50	39.00	68.80	61.30	29.90	38.00	43.90	40.60	37.50	46.90	43.30	37.70	45.60	46.90	39.90	36.70
Washington.....										34.40	51.80	45.40	40.15	50.78	40.98	31.60	26.04

Southern District																	
	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.
Alexander.....																	
Bond.....	26.52	50.89	47.58	52.93	55.60	39.47	41.76	45.41	49.56	32.18	61.58	52.54	51.66	31.99	37.98	26.75	41.90
Clay.....	33.70	49.40	55.00	59.50	62.60	43.20	44.80	37.40	43.40			54.20	66.60	48.50	50.60	44.82	44.53
Clinton.....																	
Edwards.....																	
Franklin.....																	
Gallatin.....																	
Hamilton.....																	
Jackson.....																	
Madison.....					48.19						47.40	56.40	40.10	36.90	39.70	30.18	49.97
												33.70	36.71	40.26	33.84	34.78	44.82

	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	Aver.
Marion.....								40.70	35.50	55.10	59.80	37.30	44.30	38.00	45.53
Massac.....															46.43
Perry.....							55.10	56.30	41.00	70.80	57.20	54.70	44.50	36.60	41.30
Pope.....															40.58
Randolph.....															46.76
St. Clair.....	31.28	44.88	37.87	43.02	48.46	41.26	40.83	25.20	34.66	37.37	43.15	40.10	40.64	44.34	41.20
Union.....							52.30	53.20	37.60	56.10	61.50	52.71	41.90	39.37	39.87
Wabash.....															44.99
Washington.....															40.75
Wayne.....	28.73	52.86													27.89
White.....															39.91
															49.97
Southern District.															
Alexander.....	37.74	50.51	39.56	38.71	48.79	30.51	33.57	39.36	44.10	48.66	42.42	36.89	31.66	33.07	41.35
Bond.....	37.37	39.37	33.57	46.46	41.12	31.93	37.19	42.36	42.97	52.39	34.20	41.23	28.32	39.07	42.79
Clay.....	48.51	47.29	37.50	39.70	30.71	30.77	34.07	34.69	40.61	59.82	33.49	38.80	31.21	30.36	42.43
Clinton.....	37.18	37.96	31.64	39.72	39.81	27.04	38.93	43.03	41.10	59.82	32.16	39.07	27.27	35.91	37.08
Edwards.....			27.73			31.67	35.09	46.38	50.58	59.82	41.36	41.28	33.89	35.91	41.73
Franklin.....			27.73			37.82	31.93	30.58	43.73	43.09	49.19	37.04	28.83	32.77	37.50
Gallatin.....	46.52	56.12	42.60	31.11	45.88	36.26	36.88	32.09	44.37	51.99	49.12	38.47	28.83	34.29	42.28
Hamilton.....	36.88	53.30	36.50		37.23			36.54	52.02	51.99	41.75	36.73	29.56	32.01	40.86
Hardin.....															*46.54
Jackson.....	37.85	48.59	23.81		37.31	31.52	34.15	36.58	44.48	53.12	34.93	37.35	21.96	33.34	36.45
Jefferson.....								41.25	41.03	56.90	33.66	36.37	27.36	36.78	39.13
Johnson.....								40.92	43.87	49.07	43.02	37.05	28.08	32.18	39.04
Lawrence.....	48.02	53.65	44.99	37.07			35.25	37.37	51.69	49.37	38.50	46.94	37.63	37.27	43.15
Madison.....	36.88	33.49	29.02	48.71											37.42
Marion.....	40.16	53.24	35.04												37.42
Massac.....	36.30	54.98	48.05	32.78	45.23	34.61	41.11	41.86	49.08	55.67	47.92	46.98	41.28	50.22	44.83
Monroe.....															*39.25
Perry.....	41.18	55.63	45.32		44.62	31.93	31.90	43.73	43.09	52.03	37.04	37.48	28.83	32.77	36.90
Pope.....															46.54
Pulaski.....															*41.35
Randolph.....	38.56	47.94	33.71	44.67	39.81	29.59	34.66	38.31	43.23	54.91	28.25	35.32	23.22	36.65	38.37
Richland.....	46.27	47.35	36.18	35.49	48.15	31.07	30.42	39.06	47.09	48.33	31.70	31.90	26.59	30.06	38.01
St. Clair.....	37.11	42.93	33.97	42.71	38.95	27.83	31.91	39.40	40.67	53.33	34.86	32.44	26.59	38.43	40.13
Saline.....															37.86
Union.....															37.86
Wabash.....	40.62	59.22	36.45	40.21	43.85	35.14	36.71	30.81	53.71	64.68	46.63	43.54	34.38	38.03	41.06
Washington.....								45.34	49.26	56.81	39.88	39.33	34.31	35.36	40.39
Wayne.....	38.62							38.02	41.51	57.59	37.30	30.38	28.02	30.15	38.09
Williamson.....						27.00	34.16	42.90	50.93	56.94	34.55	36.76	28.31	32.18	35.57
White.....	46.52	56.12	42.60		45.58	36.26	36.88	32.09	44.37	51.34	35.26	37.78	28.11	34.10	42.22

* Average of surrounding counties.

TABLE 3.—RAINFALL AT CERTAIN POINTS IN THE STATE. LENGTH OF RECORD IN YEARS; MONTHLY RECORDS.

NORTHERN DISTRICT.	No. of years.	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
		Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.
Bureau, Walnut.....	10	1.91	7	0	1.64	8	0	2.87	3	0	2.56	6	0	4.19	2	3	4.26	2	2
Carroll, Ianark.....	15	1.45	10	0	1.34	12	0	2.29	5	0	2.97	2	1	4.76	2	5	4.65	4	3
Cook, Chicago.....	31	2.04	19	0	2.32	14	0	2.54	11	1	2.63	9	2	4.06	9	4	3.76	6	3
Cook, LaGrange.....	11	2.04	8	1	1.84	7	0	2.69	3	0	2.20	6	0	3.88	2	2	5.50	1	3
DeKalb, Sycamore.....	18	1.81	13	0	1.86	12	0	2.39	8	0	2.81	7	0	3.77	4	2	3.93	7	5
Henry, Galva.....	10	1.63	8	0	1.31	9	0	2.89	2	0	2.39	5	0	3.91	2	2	3.67	4	2
Jo Daviess, Dubuque, Ia..	30	1.54	21	0	1.47	22	0	2.37	15	0	2.87	9	0	4.22	2	4	4.42	4	9
Kane, Aurora.....	22	2.24	12	1	2.80	10	2	2.50	6	0	2.69	7	0	4.27	2	6	3.96	6	4
Kankakee, Kankakee.....	10	1.88	6	0	1.67	5	0	2.97	4	2	2.29	5	0	4.34	2	1	2.54	5	0
Kendall, Osvego.....	13	2.24	8	1	1.76	10	0	2.43	4	0	2.40	5	0	4.07	3	3	3.66	5	2
LaSalle, Ottawa.....	16	2.54	9	0	2.12	8	0	2.89	4	0	2.29	8	0	4.42	4	2	4.17	4	4
LaSalle, Streator.....	10	1.92	7	0	1.46	8	0	3.22	2	1	1.97	6	1	3.12	3	1	3.47	4	2
Lee, Dixon.....	11	1.67	5	0	1.36	10	0	2.55	4	0	2.34	5	0	4.90	1	3	3.60	3	1
Livingston, Dwight.....	10	2.21	7	0	2.03	5	0	3.50	1	1	1.95	4	0	3.90	2	1	5.02	0	3
McHenry, Riley.....	34	2.03	10	0	1.81	25	0	2.48	17	2	2.42	9	0	3.78	6	3	4.14	6	5
Peoria, Peoria.....	47	1.73	32	0	1.93	29	0	2.51	14	0	3.01	13	2	3.80	10	9	4.01	11	8
Rock Island, R. I. Arsenal.	15	1.96	8	0	1.48	11	0	2.96	7	1	2.65	5	0	3.70	3	2	3.73	3	1
Davenport, Iowa.....	31	1.68	21	0	1.58	26	0	2.24	15	0	2.68	11	0	4.27	6	7	4.15	5	5
Stark, Elmira.....	19	1.81	9	0	1.67	9	0	2.26	8	0	3.08	1	0	4.04	3	2	3.74	3	3
Warren, Monmouth.....	11	1.80	7	0	2.31	7	1	2.33	3	0	2.59	2	0	3.39	2	2	4.05	2	1
Whiteside, Clinton, Iowa..	24	1.81	14	0	2.02	17	0	2.25	10	0	2.75	9	1	4.55	2	5	3.86	2	6
Will, Joliet.....	10	2.19	6	1	2.02	5	0	3.51	1	1	1.66	4	0	3.90	4	2	4.21	3	2
Winnebago, Rockford.....	27	2.64	9	0	2.43	13	3	2.59	8	0	2.79	7	0	4.14	3	8	4.65	3	6
Winnebago, Winnebago....	29	2.02	11	0	1.79	16	0	2.63	10	0	3.04	6	0	4.25	5	6	4.14	5	6

TABLE 3.—RAINFALL AT CERTAIN POINTS IN THE STATE. LENGTH OF RECORD IN YEARS; MONTHLY RECORDS—Continued.

NORTHERN DISTRICT.	No. of years.	JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.		
		Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.
Bureau, Walnut.....	10	4.23	4	3	2.84	5	1	3.81	1	1	1.65	7	0	1.80	6	0	1.43	9	0
Carroll, Lanark.....	15	3.91	4	3	2.61	5	1	2.92	6	1	2.20	6	0	2.00	9	0	1.76	8	0
Cook, Chicago.....	31	3.35	6	4	2.81	11	5	3.15	12	5	2.45	14	3	2.64	12	1	2.03	20	1
Cook, LaGrange.....	11	4.49	0	2	2.89	2	0	3.45	5	1	1.45	8	0	2.65	3	0	1.75	8	0
DeKalb, Sycamore.....	18	3.55	4	2	3.29	7	3	3.05	6	3	2.12	9	0	2.24	9	0	1.74	10	0
Henry, Galva.....	10	4.33	3	2	3.28	4	2	4.19	0	2	1.81	6	0	1.79	6	0	1.29	9	0
Jo Daviess, Dubuque, Ia..	30	4.24	6	8	3.12	12	3	4.47	3	7	2.49	11	2	2.08	19	0	1.72	19	0
Kane, Aurora.....	22	3.47	5	2	2.99	8	2	2.87	9	2	2.83	8	2	2.83	7	0	2.19	12	0
Kankakee, Kankakee.....	10	2.74	3	1	2.34	3	0	3.47	3	1	1.59	7	0	2.38	2	0	1.97	4	0
Kendall, Oswego.....	13	3.12	4	0	2.46	6	0	2.85	5	2	1.78	7	0	2.90	3	0	2.01	9	0
LaSalle, Ottawa.....	16	4.12	5	2	3.01	6	1	3.31	3	3	1.74	10	0	3.04	2	0	1.89	9	0
LaSalle, Streator.....	10	4.38	1	2	3.77	3	3	2.93	2	0	1.60	4	0	2.83	2	0	1.73	7	0
Lee, Dixon.....	11	4.12	3	2	2.81	6	2	3.03	2	0	1.87	6	0	1.74	7	0	1.15	8	0
Livingston, Dwight.....	10	3.16	2	2	2.53	3	0	2.74	4	0	2.21	5	0	2.69	2	0	1.35	6	0
McHenry, Riley.....	34	3.25	7	3	2.98	12	2	3.38	12	4	2.42	13	2	1.62	18	0	1.90	21	0
Peoria, Peoria.....	47	3.44	10	9	2.88	14	2	3.57	8	5	2.26	20	0	2.63	18	0	2.21	25	1
Rock Island, R. I. Arsenal.	15	3.60	5	3	3.34	3	1	2.93	4	1	1.59	11	0	2.24	7	1	1.66	9	0
Davenport, Iowa.....	31	3.66	4	4	3.24	10	3	3.12	10	1	2.40	17	2	1.81	19	0	1.69	22	0
Stark, Elmira.....	19	3.21	4	1	3.64	5	2	3.05	7	2	2.13	9	0	1.89	10	0	1.67	10	0
Warren, Monmouth.....	11	4.14	3	1	4.25	2	3	4.13	0	2	1.76	5	0	1.53	7	0	1.73	8	0
Whiteside, Clinton, Ia.....	24	4.07	3	6	2.77	10	2	3.21	8	2	2.26	13	0	1.92	15	0	1.83	13	0
Will, Joliet.....	10	4.08	3	1	3.31	2	1	2.86	3	2	1.98	5	0	2.62	3	0	2.32	5	1
Winnebago, Rockford.....	27	4.13	5	3	3.07	11	3	3.18	12	2	2.74	12	3	2.38	10	0	2.21	12	1
Winnebago, Winnebago.....	29	3.84	4	3	3.18	11	5	3.40	9	2	2.16	4	1	2.76	14	0	2.13	5	1

Counties, Stations.

TABLE 3.—RAINFALL AT CERTAIN POINTS IN THE STATE. LENGTH OF RECORD IN YEARS; MONTHLY RECORDS—Continued.

CENTRAL DISTRICT.	No. of years.	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
		Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.
Cass, Beardstown.....	14	2.10	5	0	1.84	5	0	3.17	6	1	3.43	3	1	4.81	1	5	3.85	3	3
Champaign, Philo.....	16	2.06	9	1	2.28	7	0	2.95	4	1	3.01	6	2	4.30	3	4	4.31	2	2
Champaign, Rantoul.....	11	1.61	8	0	1.84	8	0	3.12	2	1	2.96	4	2	4.46	1	1	4.96	2	3
Champaign, Urbana.....	16	1.93	11	0	2.07	8	0	2.53	7	1	2.93	6	2	3.85	3	1	4.48	3	3
Christian, Pana.....	13	2.44	6	1	3.34	3	1	3.92	1	2	4.94	3	2	3.79	2	6	5.11	1	4
Clark, Martinsville.....	16	2.07	9	1	2.48	9	0	3.43	5	2	3.31	5	2	3.96	2	1	3.79	4	3
Coles, Charleston.....	15	2.88	9	1	2.59	6	0	3.21	5	2	3.19	4	2	4.63	0	3	5.12	1	6
Coles, Mattoon.....	19	1.74	12	0	2.17	11	0	2.99	4	0	4.73	4	4	4.73	2	1	4.78	1	5
Crawford, Palestine.....	16	2.83	6	1	3.42	4	0	4.51	4	2	3.54	5	2	3.71	2	1	4.57	1	5
Douglas, Tuscola.....	10	1.97	6	0	1.97	6	0	3.44	2	1	2.59	3	0	3.68	1	0	4.21	2	2
Edgar, Paris.....	13	1.85	6	0	1.92	6	0	2.82	4	1	3.21	3	2	4.21	1	1	4.42	2	3
Effingham.....	10	2.26	6	0	1.95	5	0	1.62	4	0	2.35	6	0	2.34	2	0	2.51	3	0
Hancock, Keokuk, Ia.....	31	1.72	21	0	1.64	25	1	2.30	12	0	3.18	7	1	4.41	4	6	4.37	3	8
Logan, Mt. Pulaski.....	10	2.16	7	0	2.20	4	0	3.51	2	1	2.15	4	0	3.29	3	1	4.25	2	2
Macon, Decatur.....	12	1.92	8	0	2.34	4	0	3.57	3	1	2.51	4	0	3.85	2	1	4.19	0	1
Macoupin, Carlinville.....	12	1.63	9	0	2.61	6	0	3.50	3	2	3.84	2	2	4.60	4	2	4.43	2	2
McLean, Bloomington.....	11	2.01	7	0	2.25	7	0	3.67	2	1	3.03	4	1	4.35	2	3	4.38	2	2
Mason, Havana.....	11	2.21	7	1	2.17	5	0	3.06	4	1	3.07	4	2	3.75	4	3	3.23	1	0
Piatt, Atwood.....	13	4.56	3	2	2.78	2	0	4.25	2	2	4.99	2	3	4.81	2	5	5.57	2	3
Pike, Griggsville.....	15	2.31	7	1	2.49	6	1	2.96	4	1	2.32	4	2	5.40	1	6	4.01	4	2
Hannibal, Mo.....	11	2.08	7	1	1.78	6	0	2.73	4	1	2.78	5	1	5.32	2	6	3.48	2	2
Sangamon, Springfield.....	24	2.26	12	0	3.16	6	2	3.03	7	1	3.22	7	3	4.76	3	7	4.45	2	3
Schuyler, Rushville.....	11	1.84	6	0	2.17	6	0	2.39	4	0	4.28	1	2	4.06	1	2	4.03	0	1
Scott, Manchester.....	20	2.91	8	1	2.71	9	2	3.39	3	2	3.42	5	1	4.42	3	4	3.44	6	2

TABLE 3.—RAINFALL AT CERTAIN POINTS IN THE STATE. LENGTH OF RECORD IN YEARS; MONTHLY RECORDS—Continued.

CENTRAL DISTRICT.	No. of years.	JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.		
		Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.
Cass, Beardstown.....	14	5.89	1	1	2.41	4	0	2.86	4	1	1.95	4	0	2.62	5	0	2.00	5	0
Champaign, Philo.....	16	3.00	4	2	2.92	7	2	2.61	8	0	2.14	8	0	3.76	6	1	2.29	6	0
Champaign, Rantoul....	11	3.70	4	0	2.95	4	1	3.80	2	0	1.78	6	0	3.03	3	0	2.11	7	1
Champaign, Urbana....	16	3.28	4	1	2.86	9	2	2.71	7	0	2.14	7	0	2.58	3	0	1.98	9	0
Christian, Pana.....	13	3.11	3	1	3.10	4	3	3.11	4	0	2.79	3	0	3.00	2	5	3.22	4	1
Clark, Martinsville.....	16	3.53	3	1	3.32	3	2	2.66	7	0	1.89	11	0	3.33	3	2	2.14	7	0
Coles, Charleston.....	15	3.63	3	3	2.94	4	1	3.19	4	1	2.05	6	0	3.63	3	1	2.40	7	0
Coles, Mattoon.....	19	3.71	5	2	2.98	5	2	3.15	7	1	1.90	10	0	3.22	2	1	2.47	8	0
Crawford, Palestine.....	16	3.37	6	3	3.39	1	2	3.20	7	1	2.21	6	0	4.05	0	1	3.35	4	0
Douglas, Tuscola.....	10	3.54	2	1	3.05	3	1	3.46	3	1	2.17	6	0	2.95	2	0	2.91	3	0
Edgar, Paris.....	13	3.18	4	3	2.99	3	0	2.97	3	0	2.17	5	0	3.91	1	2	2.59	4	0
Effingham, Effingham....	10	2.60	3	0	2.26	5	0	2.40	5	0	1.77	6	0	2.77	2	0	2.56	5	0
Hancock, Keokuk, Ia.....	31	4.33	4	10	3.06	11	3	3.68	7	4	2.66	12	3	1.98	15	0	1.63	24	0
Logan, Mt. Pulaski.....	10	3.45	2	1	2.65	6	1	3.45	7	0	1.80	6	0	2.35	5	0	2.28	5	1
Macon, Decatur.....	12	3.18	3	2	2.60	5	1	3.41	3	0	2.00	5	0	3.00	2	0	2.66	4	1
Macoupin, Carlinville....	12	3.27	5	1	2.85	6	1	3.18	2	0	2.01	7	0	2.92	3	0	2.47	6	1
McLean, Bloomington....	11	3.83	4	3	2.59	7	0	3.66	3	1	1.58	7	0	2.59	3	0	2.14	6	1
Mason, Havana.....	11	3.81	2	1	3.08	4	1	3.44	2	1	1.19	7	0	2.18	5	0	1.89	7	1
Piatt, Atwood.....	13	4.85	3	5	1.83	5	0	4.00	2	1	2.08	4	0	4.34	0	0	2.91	1	1
Pike, Griggsville.....	15	3.80	3	3	2.23	9	1	3.81	3	2	2.99	10	0	2.45	7	0	1.90	9	1
Hannibal, Mo.....	11	4.36	4	3	2.41	7	1	3.03	3	1	1.56	8	0	2.10	6	0	1.78	2	0
Sangamon, Springfield....	24	2.64	10	1	2.67	11	1	3.56	7	4	2.57	11	4	2.94	10	1	2.43	11	1
Schuyler, Rushville.....	11	4.79	1	1	3.47	3	2	4.04	1	1	1.60	6	0	2.78	4	0	1.74	7	1
Scott, Manchester.....	20	3.51	3	3	2.79	6	0	3.13	3	2	2.55	8	0	2.44	5	0	2.56	7	0

Counties, Stations.

TABLE 3.—RAINFALL AT CERTAIN POINTS IN THE STATE. LENGTH OF RECORD IN YEARS; MONTHLY RECORDS—Continued.

SOUTHERN DISTRICT.	No. of years.	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
		Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.
Alexander, Cairo.....	31	3.40	5	4	3.57	9	5	4.01	4	6	3.42	4	3	3.95	5	3	4.16	6	7
Bond, Greenville.....	15	2.84	6	1	2.96	2	0	3.83	1	2	3.84	2	2	4.64	2	5	4.44	1	3
Clay, Flora.....	13	2.44	6	1	3.58	1	1	3.89	2	2	4.07	5	2	3.50	1	0	5.53	0	2
Edwards, Albion.....	12	2.58	5	1	2.45	5	0	5.08	0	2	3.13	4	1	4.51	2	2	4.83	1	4
Hamilton, McLeansboro..	15	3.01	6	1	2.93	3	0	4.53	2	2	3.44	3	3	3.93	3	3	3.73	0	2
Lawrence, Vincennes, Ind.	15	3.21	5	2	3.18	4	2	4.77	2	3	3.47	5	2	3.46	3	0	4.80	2	5
Massac, Paducah, Ky.....	14	4.11	3	3	3.56	4	2	4.67	2	3	3.95	3	2	4.10	3	2	3.65	5	1
Perry, St. John.....	12	1.96	8	0	2.62	4	0	4.53	1	2	3.81	0	1	4.11	2	3	3.50	0	0
Pope, Golconda.....	12	3.79	2	2	3.22	5	1	4.98	2	5	4.11	2	2	3.82	1	1	3.86	1	2
Randolph, Chester.....	10	2.17	6	0	2.20	6	0	3.53	3	2	3.70	0	2	4.57	2	3	4.23	2	3
Randolph, Jordan's Grove	11	2.51	6	1	2.84	2	0	4.09	1	2	4.34	3	3	3.11	1	1	3.94	2	2
Richland, Olney.....	15	2.53	8	1	2.76	4	0	4.47	3	3	3.68	6	3	3.43	3	3	3.80	2	1
St. Clair, Mascoutah.....	16	2.55	9	1	2.92	2	0	4.07	1	1	4.19	4	4	4.72	0	3	4.31	2	2
St. Louis, Mo.....	32	2.21	17	1	2.96	11	1	3.33	8	3	3.51	6	4	4.40	2	6	4.39	1	8
Wabash, Mt. Carmel.....	15	3.65	2	2	3.40	6	2	5.15	1	3	3.69	3	3	4.11	1	1	4.51	1	2
Washington, Dubois.....	12	2.72	3	0	3.18	4	1	4.00	1	3	4.03	3	2	4.90	0	1	4.12	1	2

Counties, Stations.

TABLE 3.—RAINFALL AT CERTAIN POINTS IN THE STATE. LENGTH OF RECORD IN YEARS; MONTHLY RECORDS—Continued.

SOUTHERN DISTRICT.	No. of years.	JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.		
		Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.	Average, in.	Years with less than 2 in.	Years over 6 in.
Alexander, Cairo.....	31	3.32	12	3	2.66	13	1	2.37	11	2	3.02	13	5	4.07	5	4	3.10	7	3
Bond, Greenville.....	15	2.99	5	2	2.47	6	0	2.85	4	0	2.19	7	0	4.30	4	3	2.76	6	0
Clay, Flora.....	13	3.08	3	1	3.11	1	1	2.78	4	0	2.30	3	0	3.98	2	2	2.42	3	0
Edwards, Albion.....	12	4.05	0	1	3.22	2	1	2.93	3	0	2.02	4	0	4.20	1	2	2.94	4	0
Hamilton, McLeansboro...	15	3.56	3	1	3.33	4	3	2.25	5	0	1.73	9	0	3.52	2	0	2.51	7	0
Lawrence, Vincennes, Ind.	15	3.90	4	3	2.94	3	0	3.00	3	1	2.13	6	0	3.79	3	4	2.70	4	0
Massac, Paducah, Ky....	14	3.46	4	1	3.51	3	4	3.20	3	0	2.65	6	2	3.90	2	4	3.10	2	1
Perry, St. John.....	12	3.36	4	2	2.26	3	0	1.92	5	0	2.12	6	0	3.31	3	0	2.33	4	0
Pope, Golconda.....	12	3.25	5	1	2.70	5	1	2.77	4	0	2.02	5	0	5.02	1	4	2.66	4	0
Randolph, Chester.....	10	3.21	2	1	2.73	4	1	2.35	5	0	2.34	6	0	3.53	4	2	2.76	4	0
Randolph, Jordan's Grove	11	2.59	5	1	2.79	4	2	2.56	2	0	2.11	7	1	4.18	2	2	2.46	5	0
Richland, Olney.....	15	3.70	4	2	2.15	4	1	2.06	6	0	1.30	5	0	4.65	3	3	2.80	6	0
St. Clair, Mascoutah.....	16	2.80	5	1	2.43	11	1	2.99	7	0	1.93	10	3	3.47	3	1	2.41	8	0
St. Louis, Mo.....	32	3.61	7	3	2.26	14	1	2.84	13	4	2.20	16	3	2.92	11	2	2.35	17	1
Wabash, Mt. Carmel.....	15	2.85	5	0	2.40	6	2	2.68	4	0	2.25	6	0	4.07	3	2	3.07	3	1
Washington, Dubois.....	12	3.80	2	2	2.50	4	0	3.90	5	2	1.66	7	0	2.52	5	0	3.46	2	1

Counties, Stations.

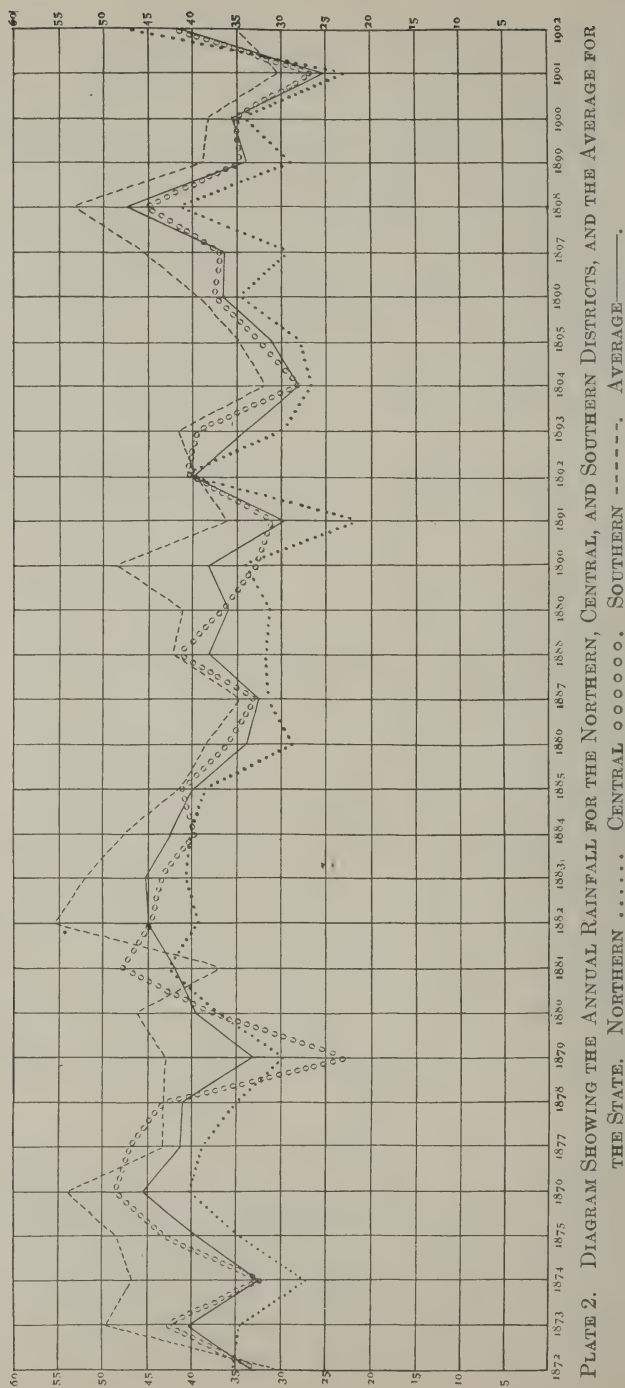


PLATE 2. DIAGRAM SHOWING THE ANNUAL RAINFALL FOR THE NORTHERN, CENTRAL, AND SOUTHERN DISTRICTS, AND THE AVERAGE FOR THE STATE. NORTHERN CENTRAL ooooo. SOUTHERN -----, AVERAGE———.

TABLE 4.—AVERAGE MONTHLY RAINFALL IN INCHES.

District.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Northern	1.97	1.94	2.72	2.51	4.05	3.85	3.67	2.97	3.21	2.04	2.23	1.81
Central	2.27	2.28	3.04	3.37	4.26	4.22	3.53	2.69	3.27	2.04	2.89	2.24
Southern	2.85	2.82	4.42	3.53	4.06	4.29	3.37	2.58	2.74	2.25	3.57	2.80
Average for State ...	2.30	2.29	3.28	3.08	4.13	4.10	3.54	2.77	3.11	2.09	2.82	2.22

RAINFALL OF THE STATE.

NORTHERN DISTRICT.—The word rainfall, as used in this bulletin, includes both rain and snow. The average for both state and districts has been obtained from observations made since 1872 and extending over a period of thirty-one years. The records previous to that date are too fragmentary for calculating yearly averages. The average rainfall for the northern district is 33.48 inches. Since 1872, thirteen years have been below the normal, the lowest being 21.46 inches in 1891, and the next 22.95 inches in 1901. The greatest rainfall for this district was in 1902, 47.22 inches and the next in 1898, 41.65 inches. Of the entire rainfall about 17.4 percent falls in winter, 28.1 percent in spring, 31.9 percent in summer, and 22.6 percent in autumn. May is the wettest month, with an average of 4.05 inches, and is followed by June, with 3.85 inches. December has least rainfall, 1.81 inches. February and January coming next with 1.94 and 1.97 inches. The rainfall is very irregular, as is shown by Table 3. A month with a rainfall of not more than two inches may usually be considered a dry month, especially in spring or summer when the growing crops need a bountiful supply of moisture. During the eighteen years that observations have been taken at Sycamore, DeKalb County, seven Aprils, four Mays, and seven Junes have had less than two inches of rainfall; that is, have been dry.

CENTRAL DISTRICT.—The central district has an average rainfall of 38.01 inches. Since 1872, fifteen years have been below the average, the lowest being 22.85 inches in 1879, the next, 26.19 inches in 1901.

The heaviest rainfall for this section was 48.67 inches in 1876 and the next, 48.11, in 1881. About 18.8 per cent of the total rainfall occurs in winter; 29.7 per cent in spring; 28.9 per cent in summer, and 22.6 percent in autumn. May and June have the heaviest rainfall, 4.26 inches, and 4.22 inches. October has the least rainfall, 2.04 inches, while December, January, and February have, respectively, 2.24, 2.27, and 2.28 inches. In this section about one-fifth of the Aprils, Mays, and Junes are dry, and about two-fifths of the Julys and Augusts.

SOUTHERN DISTRICT.—The southern district has the greatest rainfall of any part of the state, the average for the past thirty-one years being

42.19 inches, with seventeen years below normal. The least rainfall was 30.05 inches in 1872 and the next, 30.34 inches, in 1901. The greatest rainfall was 55.68 inches in 1882 and the next 54.03 inches in 1876. About 21.6 per cent of the rain falls in December, January, and February, 30.6 per cent in March, April, and May, 26 per cent in June, July, and August, and 21.8 per cent in the autumn months. March is the wettest month with an average of 4.42 inches. June is next with 4.29 inches. October has the least rainfall, 2.25 inches. Nearly one-sixth of the months of April, May, and June have less than two inches of rain, while about one-fifth of the months of July and August are dry. The nature of the soil in this part of the state is such that a short drouth or a heavy rainfall produces more injurious effects upon the growth of cereal crops than in the central and northern parts of the state.

ENTIRE STATE.—The average rainfall for the state is 37.39 inches. The least was 25 inches in 1901, the next being 28.33 inches in 1894. The greatest rainfall was in 1898, 47.39 inches, and the next was 45.47 inches in 1876; 1882 and 1883 had about 45 inches each. The six most northern counties show an average of 11.3 inches less than the seven most southern counties.

A peculiarity in the distribution of the rainfall in the southern part of the state is due to the topography of that region. The Ozark Ridge, spoken of before, extends across the northern parts of Union, Johnson, Pope, and Hardin counties with an average altitude of about 800 feet. This ridge causes a much heavier rainfall in these counties, amounting to 7.15 inches more annually than in the counties immediately north of the ridge. This difference is, of course, due to the greater condensation of the moisture as the south winds pass over this higher region. Another rainy region occurs along the Wabash river extending north into Crawford County, giving to the counties along the river about three inches more rainfall than to those in the next tier west.

This is probably due to the break in the Ozark Ridge, through which the Ohio River passes. The moisture is carried through this gap without condensation, and is then rather uniformly distributed to the north. It shows what the condition of southern Illinois would be without the Ozark Ridge. A corresponding increase of rainfall, but not so noticeable, is found along the Mississippi River as far north as Madison County.

TABLE 5.—AVERAGE TEMPERATURE, MONTHLY AND ANNUAL.
DEGREES FAHRENHEIT.

Counties.—Northern District.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual
Boone	18.4	20.8	30.8	46.6	55.7	67.0	72.1	69.8	61.7	49.4	33.9	22.0	45.7
Bureau	23.3	32.1	35.3	51.1	62.4	72.2	76.0	73.5	65.7	54.7	38.1	25.7	50.0
Carroll	20.4	24.0	32.5	48.4	59.8	68.9	73.6	70.7	62.8	50.6	35.2	25.2	47.4
Cook	23.6	24.8	34.0	44.2	54.6	66.9	72.5	71.1	63.3	52.8	38.5	28.1	47.9
DeKalb	20.2	21.9	32.4	47.9	58.8	68.9	72.6	69.7	63.0	50.2	34.6	28.2	47.4
DuPage	20.8	21.6	33.4	48.4	59.2	69.2	73.6	71.8	63.4	51.0	36.2	26.4	47.9
Ford	24.9	24.1	36.9	50.5	62.0	71.6	76.9	73.6	65.3	54.0	40.1	29.5	50.8
Grundy	24.0	23.2	35.6	49.7	61.6	70.9	75.4	72.6	64.3	53.0	39.4	30.2	50.0
Henderson	23.3	32.2	36.6	51.5	62.6	71.3	75.5	73.2	65.5	54.2	38.4	31.5	50.5
Henry	22.3	30.9	35.5	51.0	62.3	71.1	75.3	73.8	65.6	53.9	37.0	26.8	49.6
Iroquois	24.8	23.1	36.0	49.1	60.2	70.5	74.8	71.6	64.3	53.4	39.7	29.1	49.7
Jo Daviess	19.2	21.5	33.4	49.0	60.6	69.0	77.1	71.8	63.4	52.1	35.4	34.4	48.9
Kane	20.3	22.5	33.6	48.5	59.5	69.8	74.2	71.9	66.3	52.4	36.3	25.8	48.4
Kankakee	22.4	22.9	35.5	48.7	60.4	70.1	73.3	71.3	65.0	50.6	35.7	30.4	48.8
Kendall	19.7	22.2	34.0	47.4	57.4	69.2	72.4	69.4	63.8	48.0	34.7	27.4	47.6
Knox	24.5	21.4	35.5	50.9	62.4	70.9	75.1	73.1	67.0	53.8	39.0	24.3	49.8
Lake	23.5	23.1	32.2	45.8	55.7	65.1	70.5	69.5	62.7	49.9	35.8	29.0	46.9
LaSalle	23.4	24.9	35.9	50.7	61.2	71.7	75.7	72.5	65.5	53.8	38.9	29.0	50.3
Lee	22.3	19.6	33.8	48.8	60.8	69.9	74.6	72.5	64.4	52.6	36.6	24.7	48.4
Livingston	25.4	25.0	35.1	49.9	60.6	70.5	75.8	72.7	65.4	51.9	39.3	30.6	50.6
McHenry	18.5	19.7	30.8	46.3	57.9	66.4	71.8	69.5	61.7	48.3	33.7	23.4	45.7
Marshall	26.6	23.5	35.8	52.4	62.0	71.4	76.5	73.3	65.0	53.4	40.1	32.1	51.0
Mercer	21.8	22.5	35.4	48.1	61.4	70.8	75.4	73.0	65.1	53.5	37.9	28.4	49.4
Ogle	21.0	19.9	34.2	49.7	60.3	68.0	74.3	72.5	64.2	52.8	37.1	24.8	48.2
Peoria	24.6	27.3	33.7	53.4	63.6	74.3	78.3	74.8	67.3	54.4	39.8	30.7	50.8
Putnam	21.6	25.5	35.1	50.9	59.6	70.9	74.1	72.4	64.6	50.7	35.4	30.1	49.4
Rock Island	21.7	23.1	35.0	45.2	61.0	70.5	75.3	72.6	64.6	53.3	37.7	27.2	48.9
Stark	22.7	20.6	35.8	50.9	61.8	71.0	75.5	72.8	66.0	53.8	35.9	25.8	49.4
Stephenson	19.1	20.3	31.8	47.0	58.5	69.0	73.3	70.9	63.0	50.7	35.3	25.5	47.0
Warren	23.3	32.2	36.6	51.5	62.6	71.3	75.5	73.2	65.5	54.2	38.4	31.5	50.5
Whiteside	19.4	20.9	32.9	49.3	60.5	69.9	74.1	71.5	63.0	51.2	35.4	24.9	47.8
Will.	23.2	23.1	35.5	50.0	61.8	71.0	74.8	72.4	64.5	52.9	39.4	27.4	49.7
Winnebago	19.1	20.3	31.8	47.0	58.5	69.0	73.3	70.9	63.0	50.7	35.3	25.5	47.0
Woodford	24.6	26.1	38.0	52.8	63.6	73.1	77.8	74.8	66.8	54.4	39.8	29.9	51.8

Counties.—Central District.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual
Adams	28.2	25.9	38.5	52.3	64.4	72.5	77.2	75.3	67.1	56.3	41.5	28.8	52.3
Brown	27.5	27.0	37.5	54.1	63.9	73.4	76.5	74.5	67.1	55.8	39.5	31.8	52.4
Calhoun	31.0	30.9	41.5	55.1	64.5	74.7	77.8	75.5	69.1	57.2	43.4	33.4	54.5
Cass	27.5	27.0	37.5	54.1	63.9	73.4	76.5	74.5	67.1	55.8	39.5	31.8	52.4
Champaign	25.5	25.9	37.6	51.2	61.6	71.8	75.6	73.0	65.6	53.3	39.7	30.4	50.9
Christian	28.2	28.7	38.3	53.3	63.5	72.8	76.7	74.9	67.8	55.4	42.4	32.8	52.9
Clark	29.6	30.5	40.4	54.2	64.4	73.0	76.6	74.7	67.5	55.6	41.5	37.7	45.8
Coles	28.4	30.0	40.0	53.6	63.5	72.9	76.2	74.7	67.9	55.7	42.5	32.6	53.3
Crawford	30.2	30.4	42.6	54.1	64.0	73.6	77.1	74.9	66.9	55.2	42.8	33.3	53.8
Cumberland	29.6	30.5	40.4	54.2	64.4	73.0	76.6	74.7	67.5	55.6	41.5	37.4	53.8
DeWitt	26.3	25.2	39.1	52.6	63.7	72.8	76.5	74.1	67.8	56.5	40.6	29.7	52.1
Douglas	27.9	24.8	39.2	52.5	63.1	73.1	76.0	74.5	67.1	55.2	41.1	30.4	52.1
Edgar	27.6	27.7	38.1	52.0	63.4	73.4	77.4	75.0	67.9	54.7	41.9	30.6	52.5
Effingham	29.8	27.7	42.1	55.7	64.5	75.5	77.5	76.0	71.2	58.5	42.7	33.0	54.5
Fayette	29.4	28.9	41.5	55.4	65.8	74.8	77.7	75.6	69.5	56.9	42.6	33.2	54.3
Fulton	26.3	22.5	37.8	52.8	64.1	73.2	76.8	75.6	67.2	56.4	39.9	28.8	51.8
Greene	27.0	29.4	39.9	55.4	63.3	73.5	76.7	74.3	67.2	54.7	41.2	33.3	53.0
Hancock	24.7	24.0	37.5	52.5	59.9	72.4	78.6	74.6	66.7	55.0	39.2	26.4	50.9
Jasper	30.2	30.4	42.6	54.1	64.0	73.6	77.1	74.9	66.9	55.2	42.8	33.3	53.8
Jersey	31.0	30.9	41.5	55.1	64.5	74.7	77.8	75.5	69.1	57.2	43.4	33.4	54.5
Logan	27.7	27.3	38.7	52.7	62.2	72.2	75.2	73.5	66.8	55.8	40.8	31.9	52.1
Macon	27.5	25.6	40.2	53.3	64.0	73.3	76.3	75.0	67.9	56.7	41.2	30.5	52.6
Macoupin	29.7	28.9	41.2	54.6	64.3	74.0	76.9	76.3	69.6	57.6	42.2	32.3	54.0
McDonough	25.4	23.3	38.6	53.3	64.2	75.2	77.1	76.3	67.4	56.4	39.0	29.2	52.1
McLean	25.0	24.8	38.0	52.0	63.3	72.4	76.6	73.1	67.6	56.4	40.0	28.9	51.5
Mason	27.8	27.7	39.9	53.4	63.8	74.2	77.5	75.9	69.0	57.8	40.8	31.5	53.3
Menard	26.8	27.7	39.5	53.4	63.3	73.0	76.8	74.4	67.5	57.0	41.0	31.8	52.7
Montgomery	30.8	28.2	41.3	54.6	67.6	74.1	77.6	76.9	69.4	58.2	43.8	31.5	54.5
Morgan	29.0	26.6	39.9	52.7	64.6	73.7	77.8	76.9	69.7	58.5	43.0	29.7	53.3
Moultrie	25.3	24.4	37.1	50.5	61.9	69.7	74.1	71.5	66.1	53.2	39.9	28.6	50.2
Platt	25.2	24.0	36.3	50.3	61.2	69.9	74.1	71.4	65.3	53.0	38.3	28.4	51.3
Pike	28.2	26.8	39.8	54.3	64.1	73.4	76.7	75.2	68.1	56.9	40.4	31.4	52.9
Sangamon	26.4	29.4	39.2	53.4	63.1	72.0	76.4	73.9	66.8	56.7	41.4	32.0	52.5
Schuyler	26.7	26.4	38.5	53.8	63.6	74.1	76.0	74.0	66.5	55.5	39.4	31.9	52.1
Scott	29.0	26.6	39.9	52.7	64.6	73.7	77.8	76.9	69.7	58.5	43.0	29.7	53.3
Shelby	25.8	29.2	38.9	53.5	63.8	72.7	77.0	74.8	67.3	54.5	41.5	33.2	52.6
Tazewell	27.0	28.5	39.4	53.3	63.1	74.0	76.5	73.9	68.0	56.4	40.1	31.7	52.6
Vermilion	26.4	26.9	38.6	51.7	62.2	72.4	75.7	73.4	66.2	54.0	39.7	30.2	51.4

TABLE 5.—AVERAGE TEMPERATURE, MONTHLY AND ANNUAL.
DEGREES FAHRENHEIT.—Continued.

Counties.—Southern District.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual
Alexander	35.4	43.8	46.8	55.2	65.4	75.6	79.1	74.2	70.6	58.9	46.7	39.4	57.1
Bond	29.2	29.8	41.0	55.2	66.5	74.5	77.7	75.5	68.4	56.0	42.5	33.9	54.2
Clay	29.9	32.3	40.8	55.1	63.6	73.2	76.4	74.3	67.7	54.9	42.9	35.5	53.9
Clinton	30.5	30.0	41.7	54.9	66.4	74.5	77.8	75.9	68.9	56.8	42.9	33.9	54.5
Edwards	32.3	33.0	43.5	55.7	66.4	75.1	78.4	76.8	69.3	57.2	44.5	33.9	55.3
Franklin	33.3	33.5	44.7	56.6	66.7	75.6	78.8	77.2	69.5	57.3	45.1	36.4	56.2
Gallatin	34.6	33.5	44.7	56.1	66.5	76.0	78.9	77.9	71.2	57.6	46.6	35.9	56.6
Hamilton	32.5	34.3	42.9	56.0	64.9	74.8	78.2	75.9	69.1	56.7	44.7	37.1	55.6
Hardin	35.5	34.0	45.5	57.3	67.2	76.3	79.7	79.7	66.4	59.2	47.2	38.1	57.2
Jackson	32.7	33.3	45.8	58.1	68.4	77.5	79.2	78.7	70.2	58.0	44.1	36.5	56.9
Jefferson	32.9	30.6	43.1	54.4	66.3	75.2	78.2	76.9	69.9	58.6	43.2	35.5	55.2
Johnson	36.0	33.2	46.3	57.8	68.6	76.4	79.9	79.2	72.5	60.0	48.1	36.4	57.9
Lawrence	31.4	30.8	40.7	55.3	65.8	75.5	78.4	75.6	69.7	56.8	43.7	35.3	54.9
Madison	28.3	31.1	41.1	55.3	65.4	73.4	77.4	74.8	68.4	55.7	42.5	34.6	54.0
Marion	31.3	32.6	41.6	56.3	64.8	75.3	77.7	73.2	66.9	55.2	41.4	36.3	54.4
Massac	37.4	35.9	49.0	59.1	69.9	78.5	81.6	80.8	74.0	62.0	48.1	39.2	59.6
Monroe	32.4	32.8	43.5	56.3	65.5	74.1	77.4	75.7	69.3	59.5	44.4	34.6	55.4
Perry	32.9	31.4	44.1	55.4	67.2	75.8	78.2	77.9	71.1	59.3	46.2	33.3	56.1
Pope	35.3	35.2	42.2	58.1	67.0	76.2	79.4	78.0	71.5	62.5	47.0	38.9	57.6
Pulaski	35.4	33.8	46.8	55.2	65.4	75.6	79.1	71.0	70.6	58.9	46.7	39.4	56.9
Randolph	32.4	32.8	43.5	56.3	65.5	74.1	77.4	75.7	69.3	59.5	44.4	34.6	55.4
Richland	31.4	32.1	42.6	54.9	65.3	75.3	78.1	75.8	69.0	56.0	43.4	35.6	54.9
St. Clair	30.9	33.2	43.3	56.5	65.8	75.4	79.0	78.7	69.8	57.1	43.1	34.9	55.6
Saline	34.6	33.5	44.7	56.1	66.5	76.0	79.7	77.9	71.2	57.6	46.6	35.9	56.6
Union	32.2	33.0	45.0	56.8	67.4	75.1	78.0	77.9	71.6	61.0	47.5	35.1	56.8
Wabash	32.6	31.9	43.2	55.0	65.2	74.9	77.9	76.6	68.9	56.5	44.4	34.1	55.1
Washington	32.0	31.2	43.2	54.8	65.4	73.5	77.1	76.1	69.3	57.3	43.3	35.6	54.9
Wayne	32.9	30.1	43.5	55.5	66.3	74.7	77.9	76.7	69.5	57.9	45.1	33.8	55.3
White	34.6	34.2	44.2	56.6	66.6	76.6	79.0	77.8	71.7	57.9	45.0	36.3	56.7
Williamson	35.8	31.5	45.9	53.1	68.7	72.3	80.0	79.3	72.0	60.9	48.4	35.8	56.9

TABLE 6.—AVERAGE MONTHLY TEMPERATURE.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver- age
Northern District	22.1	22.7	34.7	49.5	60.3	70.0	74.6	72.1	64.5	50.7	37.2	27.8	48.9
Central District	27.8	27.4	39.4	53.4	63.7	73.2	76.7	74.7	67.6	56.0	41.2	31.5	52.7
Southern District	32.9	32.8	43.8	56.0	66.4	75.2	78.5	76.6	69.9	58.4	44.7	35.8	55.9
Average for state.....	27.4	27.3	39.2	52.8	63.3	72.7	76.6	74.4	67.1	55.0	41.0	31.5	52.3

TEMPERATURE.

The state is subject to varying extremes of temperature in short periods of time, due to the passage of cyclones, as has been already explained. The average temperature for the state is 52.3° Fahrenheit. There is a gradually increasing temperature from 46.9° in the northern tier of counties to 57.6° in the southern, or a difference of 10.7°. The three summer months for the northern counties compared with the most southern ones are about 7° cooler, while the winter months are about 17.2° cooler. The temperature is more uniform in the southern part, as may be seen by comparing the average monthly temperatures for the northern and southern districts. The differences between the January temperatures of the two districts is 10.8°, while for July it is only 3.9°. The average summer temperature for the northern district is 48° higher than the winter, while in the southern part the summer is 44.4° higher than the winter.

NORTHERN DISTRICT.—The average temperature for this district is 48.9°. The coldest month is January, with an average of 22.1°, while February has 22.7°. July has the highest average temperature, 74.6°, or 52.5° above January. Boone and McHenry counties have the lowest monthly average, 18.4° and 18.5°. The lowest recorded temperature was at Riley near Marengo in McHenry County, 31° below zero, in January, 1884, and at the same place, nineteen winters have had temperature of 20° or more below zero since 1870, and during every winter since that time the temperature has been at least 10° below zero. The average of the lowest temperatures observed at the different stations in 1884 was 25.6° below zero, and 1898 is the only year in which the average of the lowest temperatures was higher than 10° below zero since 1872. The year 1875 shows the lowest annual temperature, 43.9°, or 5° below normal. The extreme range of temperature for this section is 143°. The average annual range is about 115°, varying from 100° to 128°. The seasonal range of temperature varies with the season, the average being about 75° for winter and 53° for summer, the spring and fall months varying between these. The highest temperature recorded was at Ottawa, 112° in 1901, and this summer was the hottest shown by the records, not only of this section, but of the central and southern sections.

CENTRAL DISTRICT.—The records in this part of the state are not as complete as for the northern part, very few extending as far back as 1882. The average temperature for this district is 52.7°. The extreme range of temperature is 139°. The average annual range is about 109°, varying from 95° to 130°. The seasonal range is greater during winter, being about 75°, varying from 60° to 92°, while for summer, the average range is about 50°, with a variation of from 40° to 68°. The coldest month is February, 27.4°, with January 27.8°, while the average for December is 31.5°, or one-half degree below freezing. The lowest temperature recorded in this region was in January, 1884, 28° below zero, and the highest was 112° in 1901. The average of the lowest temperatures for this district was 24.7° below zero in 1884, which was only about 1° above the same average for the northern district. At Springfield, since 1880, only three winters show a temperature of 20° or more below zero, and thirteen show 10° or more below.

SOUTHERN DISTRICT.—The records for this district, with the exception of Cairo and St. Louis, extend no further back than 1887. The average temperature is 55.9°. January and February have almost the same average temperature, 32.9° and 32.8°. No month in this section shows an average temperature below freezing. The lowest temperature observed was in February, 1899, 23° below zero in Randolph County, while the average lowest temperature for this year was 18.7° below. The highest temperature recorded was in Marion County, 115° in July, 1901, and at several places 112° and 113° were observed. The extreme range

of temperature is 138° , and an annual range of 128° has been known, although the average is about 103° . The winter range of temperature is about 75° , varying from 50° to 90° , while the summer range is about 48° , with variations from 32° to 67° .

FROST.

Data for the time of the last killing frost in spring and the first in autumn have been collected and the average time of frost for each district has been found and is shown in the accompanying table.

Districts.	Average date for last killing frost in spring.	Average date for first killing frost in autumn.	Days between killing frosts.
Northern	April 29	October 6	160
Central	April 21	October 10	172
Southern	April 14	October 18	187

From the table we see that the season without injurious frosts is nearly two weeks longer in the central and four weeks in the southern than in the northern section. The average length of time between killing frosts in the northern tier of counties is 155 days, while that of the seven southern counties is 195, or 40 days longer. Springfield gives 173 days between frosts, the average for spring and fall frosts being April 24th and October 14th. This is about the average for the central section.

TABLE 7.—PERCENT OF TIME DURING WHICH THE WIND BLOWS FROM THE DIRECTION INDICATED.

Districts.	December, January, and February.								March, April, and May.							
	N.	N.W.	W.	S.W.	S.	S.E.	E.	N.E.	N.	N.W.	W.	S.W.	S.	S.E.	E.	N.E.
Northern.....	2.4	45.	27.8	16.2	4.5	1.5	.3	1.8	6.7	23.7	9.3	16.5	11.6	7.1	7.6	17.4
Central	1.7	63.2	9.1	12.3	8.3	4.4	.2	.8	6.4	27.4	6.4	15.5	14.5	15.6	4.3	9.9
Southern	15.3	37.1	7.8	9.8	24.4	3.1	.8	1.6	11.3	16.4	4.4	16.3	32.8	11.3	1.5	6.0

Districts.	June, July, and August.								September, October, and November.							
	N.	N.W.	W.	S.W.	S.	S.E.	E.	N.E.	N.	N.W.	W.	S.W.	S.	S.E.	E.	N.E.
Northern.....	3.8	10.1	5.1	35.5	15.3	8.0	8.5	13.5	3.1	19.2	10.5	28.6	24.5	8.2	1.6	4.1
Central	3.0	4.5	1.4	43.5	21.7	10.7	3.0	12.0	2.8	19.6	4.2	27.6	26.3	16.8	.7	2.1
Southern	5.4	.8	1.8	34.4	40.6	6.7	2.2	8.1	8.4	13.9	3.0	17.2	42.3	11.3	.7	3.2

YEARLY SUMMARY.

Districts.	N.	N.W.	W.	S.W.	S.	S.E.	E.	N.E.
Northern	4.1	23.9	12.8	24.3	14.3	6.2	4.7	9.4
Central	3.5	27.8	5.0	24.4	17.9	12.9	2.1	6.3
Southern	10.1	16.8	4.2	19.4	35.2	8.1	1.4	4.8

TABLE 8.—AVERAGE HOURLY WIND VELOCITY IN MILES.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
Chicago	13.5	14.3	14.8	14.3	13.0	11.0	10.9	10.6	12.4	13.0	13.9	13.9	12.97
Davenport	8.5	9.2	10.3	10.6	9.0	7.4	6.4	6.0	7.5	7.9	8.7	8.5	8.33
Dubuque	5.8	6.1	7.2	7.2	6.2	5.4	4.7	4.4	5.2	5.6	6.0	5.6	5.8
Hannibal	9.6	10.0	11.6	11.0	9.5	8.1	7.5	6.8	8.2	8.7	9.8	9.7	9.2
Keokuk	7.8	8.2	9.4	9.0	7.5	6.5	5.9	5.4	6.4	7.0	8.0	8.0	7.4
Springfield	10.1	10.7	11.3	10.6	8.7	7.4	6.7	6.5	7.9	8.8	10.0	10.1	9.1
Cairo	8.6	9.3	10.5	9.4	7.6	6.5	5.5	5.3	6.0	6.4	8.4	8.7	7.7
St. Louis	11.2	11.4	12.1	11.3	9.9	8.9	8.2	8.1	8.6	9.7	11.1	11.1	10.1

WIND.

DIRECTION AND VELOCITY.—The state lies in the belt of prevailing westerly winds in which the general atmospheric movement is from west to east, yet the presence of the cyclones of this belt causes great variations, both in the direction and velocity of the wind. The wind direction has been determined for seasons and not for months. The velocity is given in miles per hour and was obtained from the published records of the weather bureau stations within the state and the five along the Mississippi River. The velocity was determined by the anemometer, but comparisons are very difficult, because of the varying heights of the instruments above the ground. At Chicago the anemometer is 274 feet above the ground, at St. Louis 210, and at other stations as low as 79 feet. As a consequence, Chicago shows the highest wind velocity and St. Louis next. The velocities given are taken from Davenport, Iowa, for the northern district, Springfield for the central, and Cairo for the southern.

The velocity of the wind is greater during the cooler months of the year, February, March, and April being the windiest months, while July, August, and September have the least atmospheric movement. The season of this increased velocity is very significant to the agriculturist, increasing, as it does, the amount of evaporation. In some cases the soil may need to be dried and then it is a benefit.

The direction of the wind for the northern section is southerly for 45 percent of the time, while it blows from a north, northwest, and west direction 41 percent of the time, giving a prevailing southerly wind. In the central region the southerly wind blows for 55 percent of the time while the colder winds from the north, northwest, and west blow about 36 percent of the time. In the southern section the colder winds blow for 31 percent, while the southerly winds blow for 62 percent of the time.

1. WINTER MONTHS.—During these months the northwest wind is the most frequent in all sections of the state, blowing for 45 percent of the time in the northern, 60 percent in the central, and 37 percent in the southern district. In the northern section the west is next in frequency

to the northwest, while in the central the southwest wind, and in the southern, the south wind are next in frequency. The east and northeast winds are unimportant. The velocity of the winds is quite high, being 8.7 miles an hour for the northern, 10.3 miles for the central, exceeding slightly the velocity for the spring months, and 8.9 miles for the southern section. This makes the winters of the central section slightly more disagreeable than those of the other sections.

2. SPRING MONTHS.—During this period the northwest wind is most frequent in the northern and central sections, while the south wind blows for about one-third of the time in the southern part. The northeast and east winds assume some importance during these and the summer months, owing probably to the courses of the low areas being farther south and bringing the state, and especially the northern and central parts of the state, oftener into the northern part of cyclones where the easterly winds prevail. The southerly winds blow for about 35 percent of the time in the northern part, 45 percent in the central, and about 60 percent in the southern. The velocity of the wind is at its highest during these months, the average in the northern part being 10 miles an hour, in the central 10.2 miles, and in the southern 9.2 miles. April has the highest velocity in the northern part, and March in the central and southern, being 10.6 miles, 11.3 miles, and 10.5 miles for the different sections. These high winds are apt to have a bad effect upon the unworked soils rendering them cloddy, especially during the frequent dry spells of spring.

3. SUMMER MONTHS.—During this time the southwest forms the most frequent wind in the northern section, occurring $35\frac{1}{2}$ percent of the time, and also for the central part, occurring $43\frac{1}{2}$ percent of the time. In the southern part the south wind is prevalent for $40\frac{1}{2}$ percent of the time with the southwest 34 percent. In each division the east and northeast winds are still important. The southerly winds are prevailing ones during these months, blowing 59 percent of the time in the northern district, 76 percent in the central, and 82 percent in the southern. The velocity of the wind is least during the summer, being about 6.6 miles an hour in the northern part, 6.9 miles in the central, and 5.8 miles in the southern. August shows the least atmospheric movement of any month during the year.

4. AUTUMN MONTHS.—The northwest wind becomes more frequent during this time, but the same ones are predominant as in summer. The northeast winds have become less frequent until they blow only 4 percent, 2 percent, and 3 percent in the north, center, and south, respectively. The southerly winds occur for 61 per cent of the time in the northern part, 71 per cent in the central, and 70 per cent in the southern. The velocity of the wind increases during this time until it becomes 8 miles for the northern, 8.9 miles for the central, and 7 miles for the southern part.

TABLE 9.—DAYLIGHT CLOUDINESS IN PERCENT.
NORTHERN DISTRICT.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
Chicago	60	57	57	50	49	46	36	42	43	48	59	61	51
Davenport	54	56	58	55	52	50	42	43	44	46	56	58	51
Dubuque	51	54	55	53	52	50	41	42	45	48	54	59	52
Average	55	56	57	53	51	49	40	42	44	47	56	59	51

CENTRAL DISTRICT.

Hannibal	52	54	58	53	45	42	35	33	38	38	51	56	46
Keokuk	47	48	53	49	45	43	35	33	36	36	46	51	44
Springfield	56	57	60	56	53	54	43	40	41	41	53	60	51
Average	52	53	57	53	48	46	38	35	38	38	50	56	47

SOUTHERN DISTRICT.

Cairo	59	59	57	54	51	52	45	41	42	40	55	60	51
St. Louis	51	54	50	48	46	41	37	38	36	36	48	47	45
Average	55	56.5	53.5	51	43.5	46.5	41	39.5	39	38	51.5	58.5	48

TABLE 10.—SHOWING WHAT PERCENT THE ACTUAL SUNSHINE IS OF THE POSSIBLE
SUNSHINE OF THE PLACE.

CHICAGO.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
1894	57	57	52	64	62	71	85	73	70	43	37	45	60
1895	46	67	68	68	73	83	82	79	86	77	41	28	66
1896	35	55	65	63	78	84	66	82	56	63	36	28	59
1897	38	31	50	49	62	52	59	54	71	72	32	30	50
1898	48	44	57	54	57	50	76	63	58	26	49	51	53
1899	49	42	32	65	61	71	66	75	54	51	38	37	53
1900	37	47	41	61	56	63	60	60	57	66	40	38	52
1901	40	67	36	67	50	69	77	56	67	69	52	40	58
1902	61	58	56	67	65	58	59	67	48	67	41	33	57
Average	46	52	51	62	62	67	70	68	63	59	44	37	56

ST. LOUIS.

1894	..	63	75	..	66	91	82	83	76	71	64	56	..
1895	62	74	69	71	80	72	61	76	82	79	51	48	69
1896	48	50	58	72	74	71	72	81	60	79	46	57	64
1897	56	48	46	52	75	69	81	81	90	88	52	29	64
1899	50	63	52	65	68	80	75	76	82	72	50	49	65
1900	57	49	71	68	72	61	75	80	65	67	58	51	64
1901	64	58	49	64	70	78	79	75	78	75	80	44	68
1902	70	51	51	67	61	60	75	52	57	69	38	38	57
Average	58	57	59	66	71	73	75	75	74	75	55	46	65

KEOKUK.

1901	56	70	36	54	62	63	73	75	67	65	69	38	61
1902	63	61	39	65	54	40	59	50	55	70	36	34	52

SPRINGFIELD.

1902	59	53	47	63	62	58	76	62	53	66	42	35	56
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CLOUDINESS AND SUNSHINE.

For many years the weather bureau has been collecting data that will give a close estimate of the daylight cloudiness. Table 9 gives the results of these observations expressed in per cent. November, December, January, February, March, and April are the cloudy months of the year. The northern part is cloudy during 56 percent of the daylight, the central and southern about $53\frac{1}{2}$ percent; or in other words, the northern section has about five more cloudy days than the other sections during the months named above. The percent of cloudiness is much less for the other months of the year, the northern having $45\frac{1}{2}$ percent, the central $40\frac{1}{2}$ percent, and the southern 42 percent. A large amount of cloudiness is not necessarily accompanied by a heavy rainfall, but cloudy, and consequently cooler weather is very important in the development of some crops. December is the cloudiest month of the year for the northern and southern parts, and March for the central, although December is only 1 percent less. July is the clearest month for the northern, August for the central, and October for the southern part, with July and August only 1 percent less. Table 10 gives the percent of sunshine at some of the stations. At Chicago the sun shines 56 percent of the time that it is possible for it to shine. At St. Louis the average sunshine is about 65 percent. At Keokuk and Springfield the sunshine recorders have been installed but a short time, so that no average can be given as yet. It is interesting to compare the sunshine records for 1901, a very dry year, with those for 1902, one of excessive rainfall.

GENERAL SUMMARY.

The succession of weather changes is due almost entirely to the passage of cyclones and anticyclones, or lows and highs.

The approach of a cyclone is usually indicated by the changing of the wind to a southerly or an easterly direction and a circle around the sun or moon.

If the southern part of a cyclone pass over a place the wind will at first be from the southeast or south, and will gradually shift around to the southwest, west, and northwest accompanied by a lowering of temperature. The rain will come in showers.

If the center of the cyclone pass over a place there will be a sudden shifting of the wind from a southerly to a northwest direction as the center of the storm is passed. The rainfall may be either showers or steady rain.

If the north part of the storm pass over a place the wind will blow from an easterly direction and will shift through the north to the northwest, with lowering of temperature. The rain will be a cold, steady rain, if in the warmer months, and snow, if in winter.

The rainfall for the northern district is 33.48 inches, the least being 21.46 inches in 1891, the greatest being 47.22 inches.

Seventeen and four-tenths percent of the rain falls in winter, 28.1 percent in spring, 31.9 percent in summer, and 22.6 percent in autumn. May is the wettest month.

The rainfall of the central district is 38.01 inches. The least rainfall was 22.85 inches in 1879, the greatest, 48.67 inches, in 1876. Eighteen and eight-tenths percent of the total rainfall occurs in winter, 29.7 percent in spring, 28.9 percent in summer, and 22.6 percent in autumn. May has heaviest rainfall.

The rainfall of the southern district is 42.19 inches. The least was 30.05 inches in 1872, the greatest, 55.68 inches, in 1882. About 21.6 percent falls in winter, 30.6 percent in spring, 26 percent in summer, and 21.8 percent in autumn. March has most rain.

The average rainfall for the state is 37.39 inches. The least was 25 inches in 1901, the greatest, 47.39 inches, in 1898. Six northern counties have 11.3 inches less than seven southern counties. The Ozark Ridge in the southern part of the state makes the rainfall of the counties in which it is situated 7.15 inches more than those immediately above the ridge. A rainy region is situated along the Wabash River up as far as Crawford County. The average temperature for the state is 52.3° F. Northern tier of counties 46.9°, southern counties 57.6°. Northern summers are 7° cooler than southern, while northern winters are 17.2° cooler.

The average temperature for the northern district is 48.9°. January is the coldest month, 22.1°, July is the hottest, 74.6°. Lowest temperature recorded 31° below zero. The extreme range of temperature is 143°, average annual range about 115°. Highest temperature in summer of 1901.

The average temperature for the central district is 52.7°, the extreme range being 139°; the average annual range being about 109°. Lowest temperature recorded was 28° below zero in 1884, highest 112° in 1901.

The average temperature for the southern district, 55.9°. Lowest temperature observed was 23° below zero, in February, 1899, the highest being 115° in 1901. Extreme range is 138°, with average annual range about 103°.

The average date for the last killing frost in spring is 15 days later in northern than in southern part, and the date for the first killing frost in fall is 12 days earlier than in the southern. The difference between dates of last killing and first killing frosts for extreme parts of state is 40 days.

November, December, January, February, March, and April are the cloudy months of the year, being cloudy for 56 percent of the daylight

in the northern, $53\frac{1}{2}$ in each of the other sections. The other months of the year are less cloudy, having $45\frac{1}{2}$ percent in the northern, $40\frac{1}{2}$ in the central, and 42 percent in the southern. December is the cloudiest month for the northern and southern parts, and March for the central part.

METEOROLOGICAL SUMMARY FOR THE EXPERIMENTAL STATION.

1889.	TEMPERATURES.			Rainfall in inches.	Rela- tive humid- ity.	Prevailing wind, directions.	No. of clear days.	No. of partly cloudy days.	No. of cloudy days.
	Max.	Min.	Mean.						
Jan.	57	-2	29.28	1.48	79.1	s. w.	6	13	12
Feb.	53	-7.5	23.36	2.08	78.7	s. w. & n. w.	7	17	4
March ...	72	18	39.92	1.61	78.5	n. w.	10	15	6
April	75	25	51.9	.61	69.7	n. e. & n. w.	8	18	4
May.	91	28	59.2	5.52	74.9	s. w.	1	24	6
June	88	40	65.5	6.81	79.3	s. w.	4	22	4
July.	90.5	50	72.7	5.81	80.0	s.	8	20	3
August...	89	29.5	69.2	0.60	78.2	s.	..	..	..
Sept.	87.5	32	61.32	2.74	80.1	s. w.	7	15	8
Oct.	82	25	47.26	1.42	75.2	n. w.	15	12	4
Nov.	62	4	36.82	4.38	83.4	n. w.	6	10	14
Dec.	66	15	42.71	1.82	82.6	s. w.	8	15	8
Totals ...	.....	.....	.....	34.88	.....	.....	80	177	73
Average .	76	21	49.9	2.91	78.3	s. w.	7.3	16.1	6.6
1890.									
Jan.	66	-5	33.5	5.26	88.0	n. w.	6	15	10
Feb.	68	7	34.66	1.87	85.6	s. w. & n. w.	6	12	10
March ...	61	2	33.35	2.70	79.2	n. w.	8	16	7
April	81	29	52.32	4.11	73.1	n. e.	10	15	5
May.	83	33	58.27	3.56	72.2	s. w.	14	14	3
June	96	47	74.56	3.80	77.4	s. w.	13	16	1
July.	97.5	45	73.02	2.83	77.9	n. e.	17	13	1
August...	96	44.5	68.74	1.93	71.9	n. w.	15	15	1
Sept.	89	33	60.46	1.19	76.8	n. e.	6	20	4
Oct.	76	27	52.07	2.35	79.2	n. w.	3	21	7
Nov.	68	21	42.62	1.63	74.6	n. w.	10	12	8
Dec.	58	8	30.91	.05	75.1	n. w.	7	17	7
Totals ...	.....	.....	.....	31.28	.....	.....	115	186	64
Average .	78.2	24.6	51.2	2.6	77.6	n. w.	9.7	15.5	15.3
1891.									
Jan.	57	6	30.26	0.99	84.7	s. w.	6	10	15
Feb.	61	-9	30.45	2.60	81.5	n. w.	6	11	11
March ...	65	-1	32.55	3.55	84.9	n. e. & n. w.	4	16	11
April	81	22	52.78	3.54	79.5	n. w.	8	18	4
May.	91	30	58.4	0.89	70.0	n. e.	12	14	5
June	93	49	71.9	2.08	78.5	s. w.	9	15	6
July.	93	42	70.12	1.41	79.6	s. w.	11	18	2
August...	99	40	70.21	2.86	74.0	n. w.	2	27	2
Sept.	96	41	69.2	.41	66.0	s.	6	23	1
Oct.	88.5	27	51.3	1.29	72.9	s.	13	17	1
Nov.	67	2	35.69	5.58	83.1	s.	6	13	11
Dec.	60	11	37	1.53	79.2	s.	8	17	6
Totals ...	.....	.....	.....	26.73	.....	.....	92	199	75
Average .	79.3	21	50.82	2.22	77.8	s., s. w.	7.6	16	6.1

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—Continued.

1892.	TEMPERATURES.			Rainfall in inches.	Rela- tive humid- ity.	Prevailing wind, directions.	No. of clear days.	No. of partly cloudy days.	No. of cloudy days.
	Max.	Min.	Mean.						
Jan.	57	-15	19.2	0.79	82.9	s.	6	20	5
Feb.	55	*...	33	2.64	87.6	s.	2	14	13
March ...	69	*...	36.1	2.59	82.1	s. w.	3	22	6
April	70.5	26	48.6	6.45	77.4	n. w.	3	24	3
May	82	36	57.9	7.86	81.1	s. w.	1	23	7
June	94	51	70.6	5.36	82.1	s. w.	8	20	2
July	96.5	46	73.3	2.50	80.4	s.	4	24	3
August...	94	47	71.5	2.45	81.1	w.	10	18	3
Sept.	87	42	63.9	0.93	76.3	s.	14	15	1
Oct.	88.5	19	53.6	0.93	70.5	s.	9	20	2
Nov.	64	7	34.8	4.95	83.7	s.	7	16	7
Dec.	60	-7	27.7	1.62	86.7	s.	4	16	11
Totals ...	.....	.....	.....	39.05	.....	.....	71	232	63
Average .	76.4	.....	49.1	3.25	81.0	s.	5.9	19.3	5.3
1893.									
Jan.	48	*...	14.8	1.05	86.1	n. w.	4	17	10
Feb.	51	*...	25.8	4.48	87.5	n. w.	5	14	9
March ...	76	*...	37.8	3.20	79.6	s.	2	22	7
April	75	30	49.3	7.68	76.0	s.	1	19	10
May	84	37	57.4	4.83	75.6	n. & s. w.	4	24	3
June	93	53	70.5	1.55	70.5	s.	6	18	6
July	98	48	76.4	.59	71.9	s.	1	29	1
August...	96	37	71.1	.06	66.8	n.	11	19	1
Sept.	97	31	66.5	3.62	58.6	w.	4	19	7
Oct.	84	18	53.3	1.14	77.4	s.	9	18	4
Nov.	75	6	37.3	2.98	84.8	s.	6	16	8
Dec.	63	-6	30	1.09	84.4	s.	0	18	13
Totals ...	.....	.....	.....	32.37	.....	.....	53	223	79
Average .	73	.....	49.1	2.69	76.6	s.	4.4	19	6.5
1894.									
Jan.	64	-21	29.4	1.95	84.4	s.	3	18	10
Feb.	58	-5	24.7	1.32	81.2	w.	1	19	8
March ...	77	10	43.5	2.41	83.5	s.	4	21	6
April	85	25	51.4	1.86	78.6	s.	1	22	7
May	89	32	59.6	3.32	80.7	s.	3	25	3
June	97	34	73.4	1.78	75.4	s.	5	24	1
July	98	47	73.8	1.08	68.9	s.	4	27	0
August...	99	41	72.3	2.06	72.2	w.	6	25	0
Sept.	94	38	65	4.21	84.6	s.	10	15	5
Oct.	84	28	51.9	.51	79.7	s.	5	21	5
Nov.	67	12	35.9	2.77	84.2	s.	3	18	9
Dec.	59	-4	32.9	1.44	86.2	s.	6	17	8
Totals ...	.....	.....	.....	24.72	.....	.....	51	252	62
Average .	81	19.7	51.1	2.06	79.9	s.	4.2	21	5.1

* Record incomplete.

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—Continued

1895.	TEMPERATURES.			Rainfall in inches.	Rela- tive humid- ity.	Prevailing wind, directions.	No. of clear days.	No. of partly cloudy days.	No. of cloudy days.
	Max.	Min.	Mean.						
Jan.	57	-2	29.28	1.36	93.3	n. w.	9	14	8
Feb.	53	7.5	23.36	.52	91.7	n. w.	8	17	3
March ...	84	7	35.9	.70	83.3	n. w.	7	17	7
April	88	27	52.3	2.42	78.0	n. e.	7	17	6
May	95	28	59.4	2.20	71.2	s.	14	16	1
June	98.5	42	73.3	2.24	67.0	s.	10	18	2
July	94	43	71.3	3.61	75.8	s.	5	22	4
August...	97	48	73.2	1.81	72.2	s.	6	21	4
Sept.	87.5	32	61.32	5.27	75.0	s.	12	15	3
Oct.	82	25	47.26	.21	65.2	n. w.	14	15	2
Nov.	62	4	36.82	3.07	81.1	s.	3	14	13
Dec.	66	15	42.71	5.71	87.5	s.	2	13	16
Totals ...				29.12			97	199	69
Average .	80.3	18.7	55.1	2.42	78.4	s.	8	16	5.7
1896.									
Jan.	52	-5	28.1	1.12	89.6	s.	2	13	16
Feb.	68	-4	29.6	1.95	81.8	s. w. & n. w.	3	14	12
March ...	67	6	34.4	1.22	83.0	n. w.	5	19	7
April	86	21	57.6	1.89	70.6	s. w.	10	19	1
May	91	45	68.2	5.62	76.2	s.	7	19	5
June	92	49	70.2	2.98	78.4	s.	1	24	5
July	95	49	73.8	7.87	76.3	s.	5	19	7
August...	97	44	72	3.74	80.0	s.	12	17	2
Sept.	91	30	61.9	5.84	81.4	s.	5	14	11
Oct.	79	24	48.8	.42	78.6	n.	18	9	4
Nov.	74	9	39.9	2.87	87.9	s.	6	13	11
Dec.	62	8	33.3	.39	87.0	s. w.	3	20	8
Total				35.91			77	200	89
Average .	79	23	51.4	2.92	80.9	s.	6.4	16	7.4
1897.									
Jan.	59	-15	22	4.53	95	n. w.	10	10	11
Feb.	59	-2	30	1.17	90	n. w. & n.	3	16	9
March ...	66	20	40	4.10	88	s. e.	3	17	11
April	79	21	48	3.69	82	s. w.	3	14	13
May	83	31	58	1.81	77	n. w.	6	21	4
June	93	44	69.5	5.16	79	s. e.	1	7	22
July	98	53	75.8	4.68	80	w. & n. w.	10	12	9
August ...	97	42	70.0	0.63	79.2	n. w.	13	16	2
Sept.	97.5	32	69.4	0.31	68.5	s. w.	24	5	1
Oct.	92	32	59.1	0.42	71.0	s. & s. e.	20	8	3
Nov.	69	11	39.5	4.91	86.8	n. w.	9	10	11
Dec.	59	1	26.3	2.67	93.7	n. w.	2	16	13
Total				34.08			104	152	109
Average .	79.3	22.5	50.6	2.84	82.5	n. w.	8.7	12.5	9.1

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—Continued.

1898.	TEMPERATURES.			Rainfall in inches.	Rela- tive humid- ity.	Prevailing wind, directions.	No. of clear days.	No. of partly cloudy days.	No. of cloudy days.
	Max.	Min.	Mean.						
Jan.	62	5	30.8	4.77	87.7	w.	6	11	14
Feb.	65	-6	30.3	1.43	94.2	n. w.	3	7	18
March ...	69	15	39.4	7.76	90.2	n. w.	6	17	8
April	79	22	48.5	2.71	77.3	n. w.	3	20	7
May	82	38	61.5	5.65	83.3	s. w.	4	16	10
June	90	49	73.6	6.08	80.5	s. w.	8	17	5
July	96	47	76.9	1.89	78.0	s. w.	13	6	12
August...	94	53	74.0	3.61	84.0	s. w.	9	18	4
Sept.	94	45	68.2	5.13	85.3	s. w.	4	21	6
Oct.	86	40	51.4	4.53	86.9	s.	4	17	10
Nov.	68	*...	36.1	3.01	88.8	s. w.	11	11	8
Dec.	55	*...	26.8	1.86	96.0	n. w.	10	16	5
Total ....	.....	.....	.....	48.43	.....	.....	81	177	107
Average .	78.3	.....	51.5	4.03	86.0	s. w.	6.7	14.7	8.9
1899.									
Jan.	53	-12	25.5	1.97	96.4	s. w.	5	19	7
Feb.	58	-25	18.4	2.33	96.4	s. w.	6	16	6
March ...	65	-2	32.4	1.78	94.1	n. w.	5	10	16
April	90	15	53.1	0.50	89.3	s. w. & s.	5	20	5
May	86	42	63.8	6.09	82.5	s. w.	3	19	9
June	93	50	71.4	2.29	78.3	s. & s. w.	3	25	2
July	94	51	74.4	2.65	79.3	s. w.	7	19	5
August...	96	49	75.3	2.29	77.2	s. w.	15	11	5
Sept.	99	24	63.1	1.07	74.6	s. w.	11	14	5
Oct.	87	29	57.2	5.10	78.0	s. w.	6	17	8
Nov.	69	17	43.8	1.39	88.5	n. e. & s. w.	0	19	11
Dec.	60	-6	27.8	2.14	87.6	n. w.	0	17	14
Total ....	.....	.....	.....	29.60	.....	.....	66	206	93
Average .	79.2	19.3	50.5	2.47	85.2	s. w.	5.5	17.2	7.8
1900.									
Jan.	61	-5	30.1	0.17	92.9	w.	1	20	10
Feb.	63	-6	24.0	3.59	91.2	n. w.	0	16	12
March ...	61	0	32.6	1.79	90.7	n. w.	0	17	14
April	83	24	51.2	0.84	74.9	n. e.	3	16	11
May	89	33	63.3	4.60	74.6	s. w.	1	24	6
June	90	47	69.3	4.11	82.1	n. e.	0	21	9
July	93	51	74.2	3.81	79.4	s. w.	2	5	24
August...	95	63	78.4	6.23	80.0	s.	4	26	1
Sept.	93	34	68.2	2.23	78.7	s. e. & s. w.	1	24	5
Oct.	88	32	59.9	2.29	77.6	s. e.	1	25	5
Nov.	72	12	39.6	3.42	65.7	s. w.	0	22	8
Dec.	58	1	29.9	1.00	73.9	s. w.	2	21	8
Total ....	.....	.....	.....	34.08	.....	.....	15	237	113
Average .	78.8	23.9	51.7	2.84	80.1	s. w.	1.2	19.7	9.4

* Record incomplete.

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—Continued.

1901.	TEMPERATURES.			Rainfall in inches.	Rela- tive humid- ity.	Prevailing wind, directions.	No. of clear days.	No. of partly cloudy days.	No. of cloudy days.
	Max.	Min.	Mean.						
Jan.	61	-7	27.8	1.55	92.6	n. w.	0	16	15
Feb.	47	-2	21.0	1.41	92.1	n. w.	1	21	6
March ...	70	5	37.6	3.14	85.2	s. w.	0	12	19
April	87	28	48.5	0.80	72.7	s. e.	4	13	13
May	89	38	59.2	1.93	82.1	n. e.	2	21	8
June	95	44	72.2	5.80	77.9	s. w.	2	25	3
July	104	48	79.5	2.48	77.4	s. w.	2	29	0
August...	101	54	73.8	1.68	69.7	n. e.	2	26	3
Sept.	94	33	64.6	1.38	75.6	s. w.	4	22	4
Oct.	88	29	53.5	4.10	76.4	s. w.	6	19	6
Nov.	69	16	35.8	1.31	80.5	n. w.	0	25	5
Dec.	60	-15	24.2	3.06	88.8	n. w.	0	16	15
Total ....	.....	.....	.....	28.64	.....	.....	23	245	97
Average .	80.4	22.7	49.8	2.39	80.9	s. w.	1.9	20.4	8.1
1902.									
Jan.	56	-7	25.7	0.62	83.5	n. w.	0	25	6
Feb.	48	-14	16.8	1.48	86.3	n. w.	1	21	6
March ...	70	9	40.8	1.69	81.4	s. w.	0	18	13
April	85	23	48.1	2.11	73.9	s. w. & n. w.	0	26	4
May	90	40	65.8	2.60	75.0	s. e. & s. w.	2	25	4
June	92	45	68.4	*11.73	78.1	s. w.	1	21	8
July	91	50	74.6	4.02	77.1	s. w.	13	14	4
August...	90	52	69.4	9.80	80.1	s.	6	19	6
Sept.	84	34	61.7	4.90	82.5	s.	3	15	12
Oct.	78	31	54.5	2.10	80.8	s. w.	1	24	6
Nov.	75	14	46.6	2.42	83.0	s. w.	0	18	12
Dec.	51	0	27.0	2.94	89.3	s. w.	1	15	15
Total ....	.....	.....	.....	46.41	.....	.....	28	241	96
Average .	75.9	23.1	49.9	3.87	80.9	s. w.	2.3	20.1	8

* The storm during the night of June 10 blew the rain-gauge over, but .75 inch is included, which was about the rainfall during the storm.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

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BULLETIN No. 87.

THE STRUCTURE OF THE CORN KERNEL AND THE COMPOSITION OF ITS DIFFERENT PARTS.

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The possibility of selecting seed corn for improved chemical composition by a simple mechanical examination of sections of kernels (which any one can easily make with a pocket-knife) was clearly established by the experiments reported in Bulletin No. 55, "Improvement in the Chemical Composition of the Corn Kernel"; and the practical value of this method of selecting seed corn for high protein, high oil, or other desirable qualities has been fully confirmed by subsequent investigations and trials by the Experiment Station and by practical seed-corn breeders, as shown in Bulletin No. 82, "Methods of Corn Breeding."

A considerable amount of additional data relating to this matter has been accumulating with the progress of our experiments in corn breeding, and because of the very great importance of this subject to the corn growers and corn breeders of Illinois, and also because of the marked

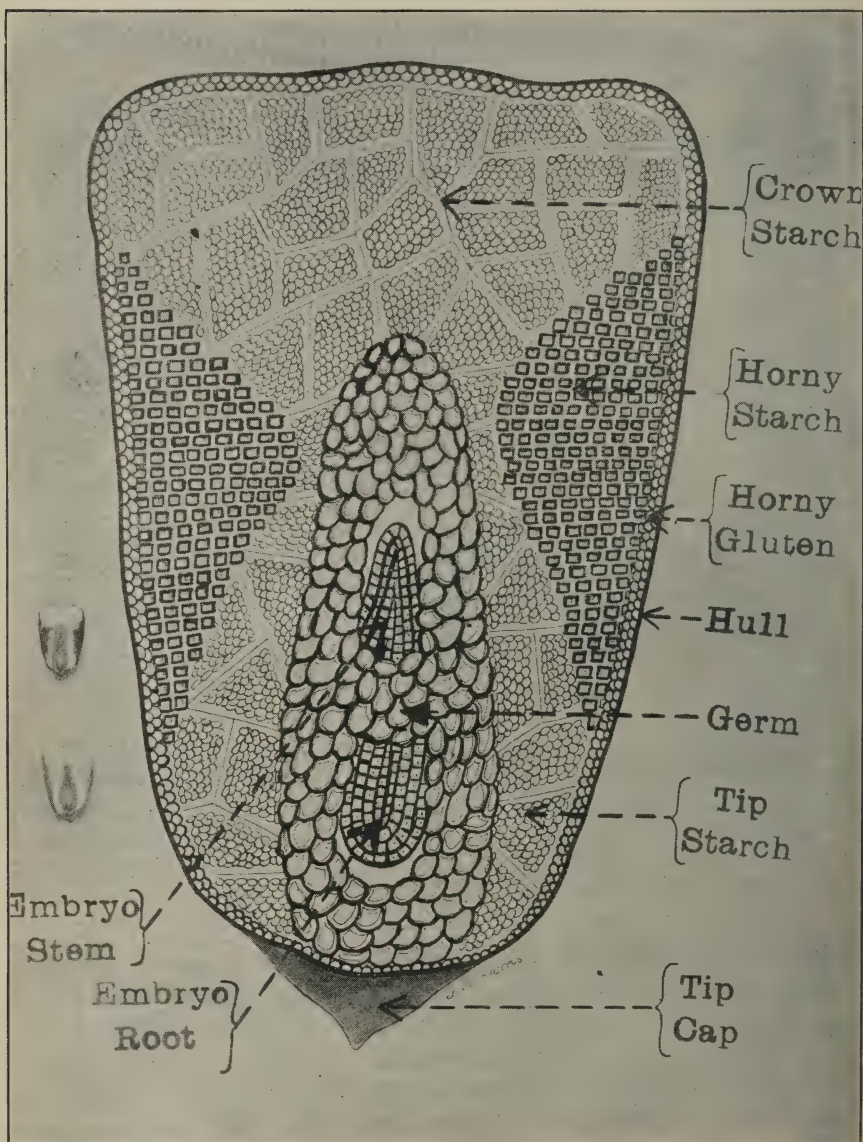


PLATE 1.—LOW-PROTEIN CORN KERNEL FROM DRAWING (SMALL KERNELS FROM PHOTOGRAPH).

interest which is manifested in this matter both by progressive, practical farmers and by scientific investigators, it has seemed advisable to publish in somewhat greater detail the results of our investigations along this line.

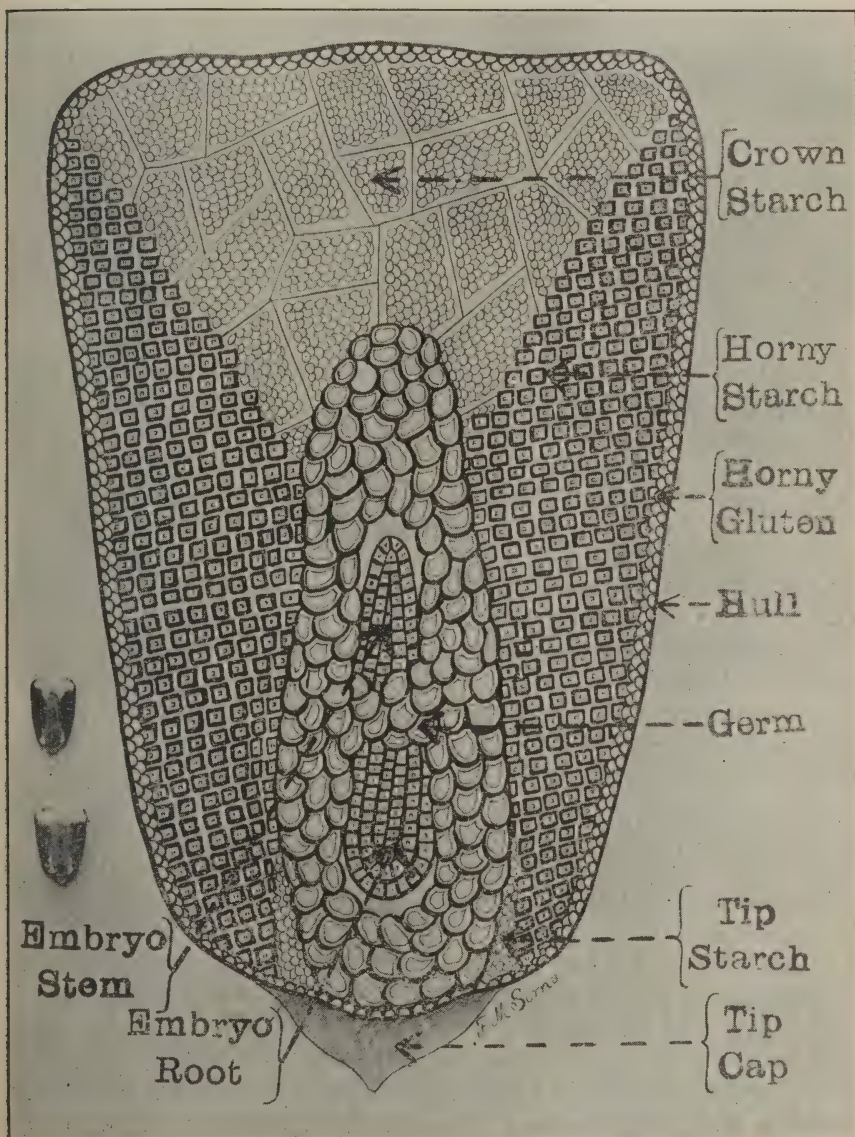


PLATE 2.—HIGH-PROTEIN CORN KERNEL FROM DRAWING (SMALL KERNELS FROM PHOTOGRAPH).

PARTS OF THE CORN KERNEL.

There are six distinctly different parts in a kernel of corn, as will be readily seen by reference to Plates 1 and 2.

1. **TIP CAP.**—This is a small cap covering the tip end of the kernel and serves as a protection to the end of the germ. It consists of material somewhat resembling the cob and occasionally in shelling corn the tip cap remains attached to the cob, leaving the tip end of the germ uncovered, but nearly always it remains on the kernel.

2. **HULL.**—This is the very thin outer covering of the kernel. It consists largely of carbohydrates, especially fiber or cellulose, although it also contains a small percentage of other constituents.

3. **HORNY GLUTENOUS PART.**—This part lies immediately underneath the hull. It constitutes a second covering of the kernel, usually much thicker than the hull. For short, it is called *horny gluten*, although it is, of course, not pure gluten. However, it is the richest in protein of any part of the corn kernel, as has been stated in bulletins already published by this station and previously by Doctor Voorhees, Director of the New Jersey Experiment Station.

4. **HORNY STARCHY PART.**—This part lies next to the horny gluten, on the back and sides of the kernel. For short, it is called *horny starch*, although it is not pure starch, as it contains considerable amounts of other constituents, especially of protein. In an examination of the kernel with the unaided eye the horny glutenous part and the horny starchy part are not readily distinguished from each other, the line between them being somewhat indefinite and indistinct. Considered both together these two parts constitute the horny part of the kernel.

5. **WHITE STARCHY PART.**—This part occupies the crown end of the kernel above the germ and it also nearly surrounds the germ toward the tip end of the kernel. For convenience this material is called white starch, although it is not pure starch as has been clearly shown in former publications. In some kernels the horny starch extends nearly or quite to the germ (near the middle of the kernel) and thus separates more or less completely the white starch into two parts which we call *crown starch* and *tip starch*.

6. **GERM.**—The germ occupies the center of the front of the kernel toward the tip end and usually extends about one-half or two-thirds of the length of the kernel. Within the body of the germ are the embryo stem pointing upward toward the crown end and the embryo root pointing downward toward the tip of the kernel, both of which are, of course, parts of the germ. These embryo parts within the germ may be easily seen by any one who will carefully shave off the front side of the germ from a kernel of corn. (See small photographic reproduction of sections of kernels of high and low protein corn in Plates 1 and 2.)

MECHANICAL SEPARATION OF THE DIFFERENT PARTS.

It is not a difficult matter to obtain very pure samples of each of the above-named parts of the corn kernel, although in making the separations there is of necessity some waste material consisting of a mixture of three different parts: namely, horny gluten, horny starch, and white starch.

By the use of a small sharp knife any one can make the following separations:

1. Tip cap.
2. Hull.
3. Horny gluten.
4. Horny starch.*
- 5a. Crown starch.
- 5b. Tip starch.
6. Germ.
7. Waste (mixed material).

In making these separations the kernels are first soaked in hot water for fifteen or twenty minutes.

The tip cap is then very easily and perfectly separated by simply cutting under one edge and then pulling it off.

The hull is separated without difficulty by peeling it off in strips. It is only necessary to use the knife to start the peeling at the tip end where the hull has been broken by removing the tip cap. With some care the hull can be completely peeled out of the dent in the corn.

The horny gluten is more easily distinguished after the hull is removed. It will be plainly seen that it covers the entire kernel, excepting possibly the exposed part of the germ. The horny gluten is removed by carefully shaving it off with a sharp knife. Adhering particles of starch can be more easily separated from the horny gluten after the shavings have been allowed to dry for some time. In scraping off these particles of horny starch or white starch adhering to the shavings, more or less horny gluten will also be scraped off, so that, while we are thus able to obtain a pure clean sample of the horny gluten, we also obtain some waste material, consisting of particles of horny gluten, horny starch, and white starch.

The germ is next removed, and with care this can be done very perfectly. If any particles of starch adhere to the germ they can easily be completely removed. After the tip cap, hull, horny gluten, and germ have been removed, the remainder of the kernel, consisting of the horny starch and white starch only, is allowed to dry, and the kernel is broken in two lengthwise.

*As used in this bulletin the term "starch" is employed in a technical or commercial sense, and not as the name of a definite chemical compound.

The crown starch is dug out with the knife as completely as possible without taking any of the horny starch.

The tip starch is next removed in the same manner as the crown starch.

The horny starch from each side usually remains in a solid piece. This is now carefully scraped to remove all adhering particles of white starch or horny gluten, the scrapings being carefully saved and added to the waste material.

By this method of separation we obtain eight different products, including the waste material, and seven of these products are pure samples of distinctly different parts of the corn kernel, excepting the crown starch and tip starch, both of which, of course, belong to the white starch; they are kept separate, however, because they are found in different places, frequently being entirely separated in the kernel, although more commonly there is some white starch continuous from crown to tip.

COMPOSITION OF THE DIFFERENT PARTS.

Table 1 shows the percentage of these eight different products, or parts, and the percentage composition of each part, also the percentage composition of the whole corn, for each of three different ears of corn. Ear No. 1 is corn of comparatively low* protein content (see foot-note). Ear No. 2 has about the usual protein content of ordinary corn. Ear No. 3 is high* protein corn (see foot-note). About 200 grams (nearly one-half pound) of kernels from each ear were separated into the different parts, and each part was then weighed and analyzed separately, another sample of the corn from each ear being analyzed to give the composition of the whole corn. (All results are given on the water-free basis.)

*It should be understood that Ear No. 1 (9.28 percent protein) and Ear No. 3 (12.85 percent protein) do not represent extremes in protein content; indeed, in our breeding of corn for low protein we have produced good ears containing less than 6.50 percent of protein, and in our high protein field we have produced corn containing over 16 percent of protein. In extremely low protein corn the percentage of horny part is very much less than in Ear No. 1, and in extremely high protein corn the tip white starch is frequently almost entirely wanting and the crown white starch very greatly reduced, both being replaced by the horny part, as shown in the drawings and also in the actual photographs of sections of kernels shown beside the drawings in Plates 1 and 2.

TABLE 1.—PERCENTAGE OF DIFFERENT PARTS AND PERCENTAGE COMPOSITION OF EACH PART.

Ear No. 1 (low in protein).					
Names of parts.	Percent of whole.	Composition of parts.			
		Protein, percent.	Oil, percent.	Ash, percent.	Carbo-hydrates, percent.
Tip caps	1.20	7.36	1.16	.91	90.57
Hulls	5.47	4.97	.92	.82	93.29
Horny gluten	7.75	19.21	4.00	.92	75.87
Horny starch	29.58	8.12	.16	.18	91.54
Crown starch	16.94	7.22	.19	.32	92.27
Tip starch	10.93	6.10	.29	.29	93.31
Germs	9.59	19.91	36.54	10.48	33.07
Mixed waste.....	18.53	9.90	1.06	.61	88.43
Whole corn.....	.....	9.28	4.20	1.41	85.11

Ear No. 2 (medium in protein).					
Tip caps	1.46	8.83	2.30	1.11	87.76
Hulls	5.93	3.96	.89	.79	94.36
Horny gluten	5.12	22.50	6.99	1.72	69.09
Horny starch	32.80	10.20	.24	.24	89.32
Crown starch	11.85	7.92	.17	.24	91.67
Tip starch	5.91	7.68	.39	.31	91.62
Germs	11.53	19.80	34.84	9.90	35.46
Mixed waste.....	25.40	11.10	1.23	.57	87.10
Whole corn.....	.....	10.95	4.33	1.55	83.17

Ear No. 3 (high in protein).					
Tip caps	1.62	4.64	1.99	1.87	91.50
Hulls	6.09	3.84	.76	1.10	94.30
Horny gluten	9.86	24.58	4.61	1.74	69.07
Horny starch	33.79	10.99	.22	.21	88.58
Crown starch	10.45	8.61	.52	.37	90.50
Tip starch	6.23	7.29	1.36	.60	90.75
Germs	11.93	19.56	33.71	10.00	36.73
Mixed waste.....	20.03	12.53	1.15	.61	85.71
Whole corn.....	.....	12.85	5.36	1.67	80.12

A careful study of Table 1 reveals some very interesting and useful facts regarding the structure of the corn kernel and the composition of the different parts. It is certainly an interesting fact that there are so

many different parts in a kernel of corn, and it is exceedingly useful to be able by a mechanical examination of corn not only to pick out high protein corn or high oil corn as one may desire, but even to separate the several distinctly different parts from one another by purely mechanical means—to separate, for example, the horny gluten, containing (in the high protein ear) nearly 25 percent of protein, and then the white starchy parts, with only 7 or 8 percent of protein; or the germs containing about 35 percent of oil and 10 percent of ash, and then the horny starchy part containing less than 0.25 percent of either oil or ash.

The hulls contain about 4 percent of protein and are clearly the poorest in protein of any part of the kernel, the next poorest being the tip caps and white starchy parts, containing about 7 or 8 percent, the tip starch being slightly poorer than the crown starch. The horny starch is richer in protein than the white starch, especially in the medium and high protein corn where the difference amounts to more than 2 percent, the horny starchy part containing from 10 to 11 percent of protein. The protein content of the germs is very uniform in the different ears, although the poorest germs are found in the high protein corn, and the richest in the low protein corn, the variation being from 19.56 to 19.91 percent. The horny gluten is the richest in protein of any part of the kernel in both ordinary and high protein corn, as was pointed out several years ago by Doctor Voorhees,* Director of the New Jersey Experiment Station, and as we have quoted in previous publications of the Illinois Experiment Station. In the high protein corn the protein content of the horny gluten amounts to 24.58 percent. In the low protein corn it is slightly less than that of the germ.

It is plainly seen that the oil in corn is very largely in the germ, although the horny gluten also contains a considerable percentage, the germ containing about 35 percent of oil and the horny gluten about 5 percent. Both the horny starch and white starch are exceedingly poor in oil, averaging about 0.25 percent, if we disregard the tip starch in Ear No. 3, which appears to have absorbed some oil directly from the germ which it adjoins and partially surrounds. The hulls contain slightly less than 1 percent of oil and the tip caps slightly more than 1 percent, and it is quite possible that this oil may have been obtained, in part at least, by absorption from the horny gluten and germ. Indeed, it seems highly probable that practically all of the true oil in the corn kernel is originally deposited in the germ and horny gluten, and that the small percentage or mere trace, which is found in the other parts is largely obtained by absorption. That such absorption actually does occur is definitely proven by the fact that the percentage of oil in hominy and hominy products increases with the age of the corn used in the milling. (Hominy

*New Jersey Agricultural Experiment Station Bulletin (1894), 105.

consists largely of the horny starch with more or less adhering white starch.)

It may be of interest to state in this connection that in 1866 Haberlandt* discovered with the microscope that the germ of the corn kernel contains a large amount of oil. He observed no oil in the remaining portions of the kernel. By chemical analysis Lenz* found, however, that after the germs were removed the remaining portion of the kernel contained 1.57 per cent of oil. These results were fully confirmed by Doctor Atwater† who found 1.63 per cent. of oil in the corn after removing the germs and adjoining material, although neither Lenz nor Atwater appear to have ascertained that the horny gluten (the aleurone layer) contains the chief percentage of oil outside of the germ.

By further reference to Table 1, it will be observed (1) that the germ contains about 10 percent of ash or mineral matter; (2), that this is about ten times the average percentage of ash contained in the other parts; and (3), that the percentage of ash in the different parts varies with the percentage of oil, to quite a noticeable degree.

Of course the percentage of carbohydrates (starch, cellulose, pentosans, etc.) varies inversely as the sum of the other constituents, being about 35 percent in the germ, 70 percent in the horny gluten, and from 90 to 95 percent in the other principal parts.

The marked degree of uniformity in the entire percentage composition of the germs from each of these three ears, whether low protein, medium protein, or high protein, seems especially noteworthy. The percentage of protein varies only from 19.56 to 19.91; the oil from 33.71 to 36.54; the ash from 9.90 to 10.48; and the carbohydrates from 33.07 to 36.73. It will also be noted that the percentages of both protein and oil are lower in the germs from high protein corn than in those from the low protein corn, although the differences are not marked.

MATHEMATICAL DISTRIBUTION OF WASTE.

It will be borne in mind that in making the mechanical separations, in order to obtain each of the seven different parts in pure condition, unmixed with any other part, there was necessarily some waste product. This waste substance amounted to about 20 per cent of the whole. As has already been explained, this mixed waste material consists of only three distinctly different parts—horny gluten, horny starch and white starch (from crown and tip), the other three parts—tip caps, hulls, and germs, being easily separated completely and in pure form.

*Allgemeine land-und forstwirtschaftliche Zeitung (1866), 257; Jahresbericht (Hoffman) über die Agricultur-Chemie (1866), 9, 106.

†Thesis, Yale College (1869); American Journal of Science and Arts (1869) (2), 48, 352.

By a simple computation the mixed waste material can be distributed among the respective parts of which it is composed, provided we may be allowed to make the assumption (which is approximately the truth) that the horny starch and white starch are present in the waste material in the same proportions as they are in the pure separated portions. Any error which might be introduced by following this assumption would have but little effect because the composition of the horny starch and white starch are not very markedly different (the protein differs by 2 to 3 percent); and also because the total amount of waste material to be distributed is only from one-third to one-half the sum of the separated horny starch and white starch.

It will be observed (see Table 1) that the mixed waste is always richer in protein than the horny starch, thus showing that, besides horny starch and white starch, it also contains more or less horny gluten, which, of course, we know to be the fact.

If in 100 grams of corn we let

x equal the number of grams of tip starch,
 Bx equal the number of grams of crown starch,
 Cx equal the number of grams of horny starch,
 y equal the number of grams of horny gluten, and
 S equal the sum of these four parts, then

$$(1) \quad x + Bx + Cx + y = S$$

Now if we let

a equal the per cent of protein in the tip starch,
 b equal the per cent of protein in the crown starch,
 c equal the per cent of protein in the horny starch,
 d equal the per cent of protein in the horny gluten, and
 s equal the number of grams of protein in all of these four parts, then

$$(2) \quad ax + bBx + cCx + dy = s$$

Thus we have two equations with which to solve for x and y , which are the only unknown quantities, B and C being factors which can be obtained by dividing the percents of separated crown starch and horny starch, respectively, by that of tip starch, and S being the sum of the separated tip starch, crown starch, horny starch, horny gluten and mixed waste, as given in Table 1; and a, b, c, d , being the respective percentages of protein in the four separated materials, tip starch, crown starch, horny starch, and horny gluten, and s being the total number of grams of protein contained in these four separated parts and in the mixed waste, all of which data are also given in Table 1.

PHYSICAL COMPOSITION OF THE CORN KERNEL.

From the above computations we obtain the results given in Table 2, which gives the total percentages of each of the seven different parts con-

tained in the corn kernel (counting crown starch and tip starch as two parts), and with no waste material.

TABLE 2.—TOTAL PERCENTAGES OF THE DIFFERENT PARTS OF THE CORN KERNEL.

Name of parts.	Ear No. 1, (low protein).	Ear No. 2, (medium protein).	Ear No. 3, (high protein).
Tip caps	1.20	1.46	1.62
Hulls	5.47	5.93	6.09
Horny gluten	11.61	8.51	13.32
Horny starch	37.15	47.08	44.89
Crown starch	21.26	17.01	13.88
Tip starch	13.71	8.48	6.28
Germ-s	9.59	11.53	11.93
Total	99.99	100.00	100.01

It will be observed that the percentages of horny gluten, horny starch, and germs are noticeably higher in the high protein corn than in the low protein corn; while the opposite is true with the white starch, the percentages of crown starch and tip starch being markedly higher in the low protein corn than they are in the high protein corn. It is noteworthy that the horny gluten in high protein corn not only contains a higher percentage of protein than the germs, but that the proportion of horny gluten in the kernel equals or exceeds that of the germs. The only discrepancies appearing in Table 2 are the low percentage of horny gluten and the high percentage of horny starch in Ear No. 2. Otherwise the percentages of parts in the medium protein ear are always intermediate between those in the other two ears, as would be expected. Even these discrepancies disappear if the two horny parts be added together and considered as one part, as is done in the practical work of selecting seed corn for higher protein content by mechanical examination, as will be seen by referring to Table 3.

TABLE 3.—PERCENTAGES OF THE DIFFERENT PARTS OF THE CORN KERNEL AS COMMONLY OBSERVED IN MECHANICAL EXAMINATION FOR SEED CORN SELECTION.

Names of parts.	Ear No. 1, (low protein).	Ear No. 2, (medium protein).	Ear No. 3, (high protein).	Average percent.
Tip caps	1.20	1.46	1.62	1.43
Hulls	5.47	5.93	6.09	5.83
Horny part	48.76	55.59	58.21	54.19
White starch	34.96	25.49	22.16	27.54
Germs	9.59	11.53	11.93	11.02
Total	99.98	100.00	100.01	100.00

In this table the crown starch and tip starch are also added together and the sum recorded as white starch. The increase in the amount of horny part (from 48.76 to 58.21 percent), and the decrease in white starch (from 34.96 to 22.16 percent) as we pass from the low protein to the high protein corn, is plainly apparent.

DISTRIBUTION OF CHEMICAL CONSTITUENTS.

Table 4 shows the location or complete distribution of the chemical constituents among the seven different physical parts of the corn kernel. In other words, this table represents the separation of 100 grams (or 100 pounds) of corn into seven different structural or physical parts, and the subsequent division of each of these parts into the four chemical constituents, protein, oil, ash, and carbohydrates.

The complete data shown in Table 4 are presented especially for the benefit of farmers who are corn breeders, and also for the benefit of the manufacturers of corn products. The agreement between the sum of the separate determinations and the direct determinations of the same constituent in the whole corn is very satisfactory, considering that these results are obtained by computation from the analyses of nine different materials, including the whole corn. The greatest difference is well within the limit of unavoidable error in sampling and analytical determinations. A careful study of this table will reveal some interesting and valuable facts. For example, it will be seen that in 100 pounds of the low protein corn the horny gluten contains only 2.23 pounds of protein; while 3.27 pounds of protein are contained in the horny gluten in 100 pounds of the high protein corn. Again, in 100 pounds of the low protein corn the horny starch contains only 3.02 pounds of protein; while 4.93 pounds of protein are contained in the horny starch in 100 pounds of the high protein corn.

On the other hand, in 100 pounds of the low protein corn the crown starch and tip starch contain 1.53 and .84 pounds of protein, respectively; while 1.20 and .60 are the respective amounts contained in the corresponding parts of the high protein corn.

If we add together the horny parts and then add together the crown starch and tip starch, as is done in the practical selection of seed corn by mechanical examination, we obtain the results shown in Table 5.

TABLE 4.—PHYSICAL AND CHEMICAL DISTRIBUTION OF 100 GRAMS (OR 100 POUNDS) OF CORN.

Ear No. 1 (low in protein).

Names of parts.	Physical distribution (grams or pounds).	Chemical distribution.			
		Protein, (grams or pounds).	Oil, (grams or pounds).	Ash, (grams or pounds).	Carbo- hydrates, (grams or pounds).
Tip caps	1.20	.09	.01	.01	1.09
Hulls	5.47	.27	.05	.04	5.10
Horny gluten	11.61	2.23	.46	.11	8.81
Horny starch	37.15	3.02	.06	.07	34.01
Crown starch	21.26	1.53	.04	.07	19.62
Tip starch	13.71	.84	.04	.04	12.79
Germes	9.59	1.91	3.50	1.01	3.17
Total	99.99	9.89	4.16	1.35	84.59
Whole corn		9.28	4.20	1.41	85.11

Ear No. 2 (medium in protein).

Tip caps	1.46	.13	.03	.02	1.28
Hulls	5.93	.23	.05	.05	5.60
Horny gluten	8.51	1.89	.59	.15	5.88
Horny starch	47.08	4.80	.11	.11	42.05
Crown starch	17.01	1.35	.03	.04	15.59
Tip starch	8.48	.65	.03	.03	7.77
Germes	11.53	2.28	4.02	1.14	4.09
Total	100.00	11.33	4.86	1.54	82.26
Whole corn .....	.....	10.95	4.33	1.55	83.17

Ear No. 3 (high in protein).

Tip caps	1.62	.08	.03	.03	1.48
Hulls	6.09	.23	.05	.07	5.74
Horny gluten	13.32	3.27	.61	.23	9.20
Horny starch	44.89	4.93	.10	.09	39.76
Crown starch	13.88	1.20	.07	.05	12.56
Tip starch	8.28	.60	.11	.05	7.51
Germes	11.93	2.33	4.02	1.19	4.38
Total	100.01	12.64	4.99	1.71	80.63
Whole corn .....	.....	12.85	5.36	1.67	80.12

TABLE 5.—POUNDS OF PROTEIN IN 100 POUNDS OF CORN.

Names of parts.	Low protein corn.	Medium protein corn.	High protein corn.
In tip caps	.09	.13	.08
In hulls	.27	.23	.23
In horny part	5.25	6.69	8.20
In white starch	2.37	2.00	1.80
In germs	1.91	2.28	2.33
Total	9.89	11.33	12.64

It will be observed that the increase in protein in high protein corn over that in low protein corn occurs almost entirely in the horny part of the corn kernel. As indicated in previous bulletins there is also a slight increase in protein in the germ, although this is quite insignificant as compared with the increase in the horny part. In passing from low protein corn to high protein corn, there is an appreciable decrease in the amount of protein contained in the white starch. Of course this is due to the marked decrease in the actual amount of white starch in high protein corn. Indeed, this decrease in the quantity of white starch is even more marked than would appear from Table 5, because the white starch in the high protein corn is actually richer in protein than that in low protein corn, as would be expected and as is shown in Table 1.

The data given in Table 5 strongly confirm the results which we have already obtained in practical experience in corn breeding. For example, we have been breeding both high protein corn and low protein corn for the past seven years. In the high protein corn we find that the proportion of horny part has increased very markedly, while the white starchy part has markedly decreased. In the low protein corn the opposite is true, the horny part having decreased and the white starchy part having markedly increased, in proportion.

By computation from the data given in Table 4, we have constructed Table 6, which shows the percentage distribution of the different chemical constituents among the several physical parts of the corn kernel.

It will be seen that as an average about 22 percent of the total protein is contained in the horny gluten, nearly 40 percent in the horny starch, and nearly 20 percent in the germ, thus these three parts contain about 80 percent of the total protein in the kernel.

The germ contains from 80 to 84 percent of the oil, while all other parts combined contain only 15 to 20 percent of the total oil in the kernel. Based upon this fact is the method for selecting high oil or low oil seed corn by mechanical examination, the ears whose kernels show a large proportion of germ being high oil corn and those with small germs

TABLE 6.—PERCENTAGE DISTRIBUTION OF CHEMICAL CONSTITUENTS AMONG PHYSICAL PARTS.

Ear No. 1 (low in protein).

* Names of parts.	Percent of total protein.	Percent of total oil.	Percent of total ash.	Percent of total carbo- hydrates.
In tip caps	.89	.33	.81	1.29
In hull.....	2.75	1.21	3.34	6.03
In horny gluten.....	22.56	11.13	7.96	10.41
In horny starch	30.51	1.43	4.98	40.22
In crown starch.....	15.52	.97	5.07	23.18
In tip starch	8.46	.95	2.96	15.12
In germs	19.31	83.99	74.87	3.75
Total	100.00	100.01	99.99	100.00

Ear No. 2 (medium in protein).

In tip caps	1.14	.69	1.06	1.56
In hull.....	2.07	1.08	3.06	6.80
In horny gluten.....	16.67	12.21	9.56	7.15
In horny starch	42.36	2.32	7.38	51.12
In crown starch.....	11.88	.59	2.67	18.96
In tip starch	5.75	.68	1.72	9.45
In germs	20.14	82.43	74.55	4.97
Total	100.01	100.00	100.00	100.01

Ear No. 3 (high in protein).

In tip caps	.59	.65	1.76	1.84
In hull.....	1.85	.93	3.90	7.12
In horny gluten.....	25.88	12.29	13.49	11.41
In horny starch	39.00	1.98	5.49	49.31
In crown starch.....	9.45	1.44	2.99	15.58
In tip starch	4.77	2.25	2.89	9.32
In germs	18.45	80.46	69.46	5.43
Total	99.99	100.00	99.98	100.01

low oil corn. (See Plate 4.) About 12 percent of the total oil is contained in the horny gluten, leaving only about 5 percent of the oil distributed among the remaining five physical parts, and, as stated above, more or less of this small amount is undoubtedly absorbed from the contiguous germ or horny gluten.

It will be noted that the ash is closely associated with the oil, nearly 75 percent of the total ash being contained in the germ, and about 10 percent in the horny gluten, as an average.

Table 7 shows, for direct comparison, the percentage distribution of the protein among the different physical parts, in each ear, the two horny parts, and also the two white starchy parts, being combined, as in Table 5.

TABLE 7.—DISTRIBUTION OF 100 GRAMS (OR 100 POUNDS) OF PROTEIN AMONG THE PHYSICAL PARTS AS OBSERVED IN MECHANICAL EXAMINATION.

Names of parts.	Low protein corn.	Medium protein corn.	High protein corn.
In tip caps	.89	1.14	.59
In hulls	2.75	2.07	1.85
In horny part	53.07	59.03	64.88
In white starch	23.98	17.63	14.22
In germs	19.31	20.14	18.45
Total	100.00	100.01	99.99

Table 7 illustrates very plainly the fact that, as we pass from low protein corn to high protein corn, the protein decreases in the white starchy part and increases in the horny part; in other words, in breeding corn for high protein, we decrease the white starchy part, which is comparatively poor in protein, and increase the horny part, which averages very much richer in protein, the horny starch containing 2 to 3 percent more protein than the white starch, and the horny gluten being richer in protein than any other part of the kernel. As a rule, in breeding for high protein there is also a slight increase in the proportion of germ, which, being rich in protein, adds somewhat to the increase in protein.

MECHANICAL METHODS OF SELECTING SEED CORN FOR IMPROVEMENT IN COMPOSITION.

As has already been shown in our Bulletin No. 82 "Methods of Corn Breeding," we have found it entirely feasible and practical to select seed corn of higher protein content by a simple mechanical examination of a few kernels from each ear. With some care any farmer or corn grower can learn to pick out high protein seed corn by dissecting and examining a few kernels from each ear (by means of a pocket-knife), selecting for high protein seed the ears whose kernels show a large proportion of horny

part, and rejecting those showing a small proportion of horny part. (See Plate 3; also Plates 1 and 2.)

HIGH PROTEIN KERNELS
(Much horny part;
little white starch).

LOW PROTEIN KERNELS
(Little horny part;
much white starch).



PLATE 3.

This method is already in use by practical corn breeders, and with a very satisfactory degree of success. For example, in selecting seed corn by this method Mr. Ralph Allen, of Tazewell County, obtained seed ears for the year 1902, which were 1.46 percent higher in protein than the rejected ears from the same lot, and for this season (1903) his selected seed ears contain 1.58 percent protein more than the ears which he has rejected. In other words, his selected seed corn is richer by 1.58 pounds of protein per 100 pounds of corn than that rejected.

The method proposed some years ago by Professor Willard, Director of the Kansas Agricultural Experiment Station, of picking out high protein seed by simply selecting for large germs enables one, as a rule, to make some gain in protein, but the gain is very much greater when the proportion of horny part is considered. In fact, from our own experience we find that the selection for a large proportion of horny part is a very much more trustworthy index than the size of the germ, in securing high protein seed, and we often find corn with large germs which is actually low in protein, because of a small percentage of protein in the remainder of the kernel. The fact that only 20 percent of the total protein of the kernel is obtained in the germ (as shown in Table 7) is evidence of the uncertainty of obtaining high protein seed corn, and of the improbability of making any very considerable gain in protein, by this method of selection. This difficulty was well understood by Professor Willard, as will be seen in the following quotation from the Kansas Experiment Station Bulletin No. 107, page 63.

"There are undoubtedly great differences in the protein content of the part of the kernel exclusive of the germ, and it is conceivable and not improbable, that a large germ, though in itself tending to produce high protein content might be overcome by the low protein of the remainder of the kernel."*

Of course, if one picks out corn with large germs and at the same time, either consciously or unconsciously, selects those ears whose kernels contain a large proportion of horny part, he may make considerable gain in protein, but in such case the gain should not be attributed solely to the large germs.

* *Protein* is substituted for *nitrogen* in this quotation.

HIGH OIL KERNELS
(Large germs).**LOW OIL KERNELS**
(Small germs).

PLATE 4.

The method of selecting seed corn for high oil content on the basis of large germs (see Plate 4) is certainly well founded, because of the fact that more than 80 percent of the total oil of the kernel is contained in the germ.

THE CORRELATION OF SOME PHYSICAL PARTS AND CHEMICAL CONSTITUENTS OF THE CORN KERNEL.

As was clearly shown in our Bulletin No. 55, there is usually a marked correlation between the percentage of germ and the percentage of oil in the corn kernel, as will be seen from the following summary of 100 *separate determinations* reported in that bulletin:

TABLE No. 8.—CORRELATION BETWEEN GERM AND OIL IN CORN KERNELS.

Number of determinations.	Small germ corn.		Large germ corn.	
	Germ, percent.	Oil, percent.	Germ, percent.	Oil, percent.
10.....	9.10	3.58	14.11	6.49
10.....	8.56	3.22	12.40	6.71
10.....	8.28	3.64	12.01	6.08
10.....	8.73	3.32	13.30	5.82
10.....	9.82	4.30	11.06	5.21
General average.....	8.90	3.61	12.57	6.06

While there is, of course, some variability due in part to the different percentages of oil in germs from different kernels (especially in kernels from different ears) and in part to the different percentages of oil in the horny gluten (and to some extent in other parts) from different ears (see Table 2), nevertheless it will be observed that there is a marked correlation between the percentage of germ and the percentage of oil in the corn kernel. In other words, the percentage of oil varies with the percentage of germ. It will be observed, however, that a high percentage of germ is accompanied by a still higher proportionate percentage of oil, indicating that increased proportion of germ in the kernel is due to an increase in the quantity of oil more largely than of the remainder of the germ.

CORRELATION BETWEEN OIL AND PROTEIN.

That there is a marked correlation between the percentages of germ and oil in the corn kernel is certainly well established; consequently, if the proportion of germ were a reliable index to the relative protein content of the kernel, there would, of course, be some marked correlation between the percentages of oil and protein in corn.

In Table 1 of Bulletin No. 55 are recorded the proximate analyses of 163 different ears of corn. Table 9 is derived from that data, and shows the percentages of oil and protein contained in the ten ears which are lowest in oil and in the ten ears which are highest in oil, the analyses being arranged in the descending order for protein.

The correlation between oil and protein is certainly very slight. In the low oil corn the oil varies from only 3.84 to 4.08 percent, while the protein varies from 9.08 to 12.96 percent. In the high oil corn the oil

varies only from 5.46 to 6.02, while the protein varies from 9.58 to 13.87 percent, making a difference of 4.29 percent protein between these extreme ears, while the difference in oil is only .09 percent between the same ears. The average percentages of oil in these two lots of corn vary from 3.99 to 5.64 percent, while the corresponding averages for protein are 11.02 and 11.19, thus showing very little correlation between the percentages of oil and protein in the corn kernel.

TABLE 9.—CORRELATION BETWEEN OIL AND PROTEIN IN THE CORN KERNEL.

Low oil corn.		High oil corn.	
Oil, percent.	Protein, percent.	Oil, percent.	Protein, percent.
3.97	12.96	5.72	13.87
3.99	12.28	5.51	13.10
4.03	11.71	5.61	12.09
4.07	11.49	5.75	11.18
3.84	11.29	5.65	10.82
4.08	11.29	5.51	10.49
3.94	10.97	5.46	10.32
4.01	9.68	5.51	10.23
3.95	9.44	6.02	10.18
4.05	9.08	5.63	9.58
Averages 3.99	11.02	5.64	11.19

Table 10 is also derived from Table 1 of Bulletin No. 55, and is similar to Table 9, except that the analyses of the ten ears lowest in protein and of the ten ears highest in protein are chosen. This shows the reverse correlation; that is, between protein and oil. Of course, the results should be practically the same as shown in Table 9, the chief value of Table 10 being that it uses almost an entirely different set of analyses, and consequently gives a duplicate illustration of the lack of correlation between these two constituents.

TABLE 10.—CORRELATION BETWEEN PROTEIN AND OIL IN THE CORN KERNEL.

Low protein corn.		High protein corn.	
Protein, percent.	Oil, percent.	Protein, percent.	Oil, percent.
9.31	4.96	13.87	5.72
8.40	4.91	13.10	5.51
8.38	4.88	12.68	5.29
9.31	4.82	12.81	5.21
8.25	4.81	12.63	5.15
9.22	4.60	13.06	4.93
9.15	4.55	12.57	4.82
9.30	4.38	12.79	4.25
9.12	4.10	12.76	4.10
9.08	4.05	12.96	3.97
Averages... 8.95	4.61	12.92	4.90

It will be observed that, although the averages for protein vary from 8.95 to 12.92 percent, the averages for oil vary only from 4.61 to 4.90 percent. These averages indicate only a slight correlation between protein and oil, and the analyses of the individual ears show that even this correlation is by no means constant.

In connection with some investigations relative to heredity Professor Frank Smith of this University, has prepared correlation tables (see Tables 11 and 12) from the 163 analyses of individual ears of corn recorded in Table 1 of Bulletin No. 55. Table 11 shows the correlation between

TABLE 11.—ONE HUNDRED SIXTY-THREE EARS OF CORN GROUPED ACCORDING TO PERCENTAGES OF PROTEIN AND CARBOHYDRATES.

Carbo- hydrates percent.	Protein, percent.													Total No. of ears.
	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	
79													1	1
79.5														
80											1			1
80.5										1	2			3
81									1	3				4
81.5							1		2	7	3			13
82							2	5	13					20
82.5					1	3	7	12	3	1				27
83					2	7	16	7						32
83.5				2	7	9	4	1						23
84				3	7	5	1							16
84.5			1	8	2									11
85			1	5										6
85.5	1	2	2	1										6
Total No. of ears.	1	2	4	19	19	24	31	25	19	12	6		1	163

The correlation of high protein with low carbohydrates and *vice versa* equals 90.05 per cent.

protein and carbohydrates, the entire 163 ears of corn being grouped according to the percentage of protein and carbohydrates which they contain. This table well illustrates what is meant by a high degree of correlation. With an increasing protein percentage there is a decreasing percentage of carbohydrates, and there are no marked exceptions to this rule. Note, for example, that there is one ear containing 14 percent of

protein, but that this ear contains only 79 percent of carbohydrates, being the highest in protein and also the lowest in carbohydrates of the 163 ears. There are nineteen ears containing only 12 percent of protein, but none of these nineteen ears contains less than 81 percent of carbohydrates; thirteen of them contain 82 percent of carbohydrates, while five others are within one-half percent of that amount. One ear contains only 8 percent of protein, but this ear contains 85.5 percent of carbohydrates, being both the lowest in protein and the highest in carbohydrates of the 163 ears. It will be observed that of the 163 ears, several groups fall in the squares representing low protein (8 to 10 percent) and high carbohydrates (84 to 85.5 percent); also that many ears fall in the squares representing high protein (12 to 14 percent) and low carbohydrates (80 to 82 percent); so that, including the ears with medium content of protein and carbohydrates, we find that the group numbers of 163 ears fall almost in a straight line extending from the lower left-hand corner to the upper right-hand corner of the table. It will be seen that no ears whatever fall in the squares representing high protein and high carbohydrates, or in those representing low protein and low carbohydrates. By mathematical computation Professor Smith has found that we have in this table 90.05 percent of a perfect correlation.

TABLE 12.—ONE HUNDRED SIXTY-THREE EARS OF CORN GROUPED ACCORDING TO PERCENTAGES OF PROTEIN AND OIL.

Oil, percent.	Protein, percent.													Total No. of ears.
	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	
3.8								1						1
4.0			2	2			2	3	1	1	1			12
4.2				3	2	3	3	2	3		2			18
4.4				3	4	2	7	3	2					21
4.6			2	1	1	8	5	8	4	3				32
4.8	1	1		5	6	3	7	2	4	5				34
5.0		1		2	1	3	3	5	4		1			20
5.2				2	3	2	2	1		3	1			14
5.4						2								2
5.6				1	1	1	1		1		1			6
5.8							1						1	2
6.0					1									1
Total No. of ears.	1	2	4	19	19	24	31	25	19	12	6		1	163

The correlation of high protein with high oil and of low protein with low oil equals 3.81 percent.

Table 12 shows the degree of correlation which exists between oil and protein. It will be seen that there is no such grouping as in Table 11. In other words, there is no marked correlation between the oil and protein in corn. Some ears are rich in one of these constituents and poor in the other; other ears are rich in both, and still others are poor in both, so that the grouping of the numbers of ears according to the percentages of oil and protein which they contain resembles a circle much more nearly than a straight line. By computation it is found that there is a slight tendency for the protein to increase with increasing oil content, but the degree of correlation amounts to only 3.81 percent of a perfect correlation.

All of the above data tend to prove that, as the percentage of protein increases in corn the starch decreases, while the oil remains almost unchanged; and that we may increase or decrease the percentage of oil or of germ in corn without markedly affecting the percentage of protein. This was the conclusion drawn when the above-mentioned 163 ears of corn were analyzed more than six years ago. The different strains of corn which we have finally produced in our regular corn breeding work furnish us excellent material for ascertaining what effect is produced upon the oil content of corn by breeding for a higher or lower protein content; and, *vice versa*, what effect is produced upon the protein content by breeding for a higher or lower oil content.

In 1900 we planted ten field rows (called the "mixed plot") with two kinds of corn in every row, one kind having been bred for four years for high oil content, the other (originally from the same variety and stock) having been bred during the same four years for low oil content. These two kinds of seed were planted in every row and in fact in every hill, the low oil kernels and the high oil kernels in the same hill—just far enough apart so that the identity of the individual plants could be known as they grew during the season. The corn from each of the ten rows was harvested in two lots, one lot being corn from high oil seed and the other lot being from low oil seed. The two lots from each row were kept separate, the one being labeled as corn from the "high oil side" of the row and the other from the "low oil side."

The percentages of oil and of protein contained in these different lots of corn are shown in Table 13.

These data are considered very reliable, both kinds of corn having been grown during the same season and in exactly the same soil and each individual sample whose composition is shown in Table 13 being a composite sample representing many ears. The average difference in oil content between the high oil side and the low oil side is 1.97 percent of oil, while the average difference in protein is 0.18 percent. Considering that the percentage of protein in the corn is twice as large as the percentage of oil, it will be seen that there is less than 5 percent of a perfect correlation between the oil and protein.

TABLE 13.—OIL AND PROTEIN IN CORN HARVESTED FROM THE "MIXED OIL" PLOT IN 1900.

Row No.	Low oil side.		High oil side.	
	Oil, percent.	Protein, percent.	Oil, percent.	Protein, percent.
1	3.93	10.07	5.61	10.06
2	3.78	9.26	5.74	9.05
3	3.73	10.21	5.88	9.12
4	3.75	8.47	5.99	9.65
5	3.89	9.39	5.71	10.08
6	3.80	9.77	5.91	10.23
7	3.60	9.80	5.60	9.91
8	3.58	9.65	5.84	10.32
9	4.22	9.18	5.68	9.15
10	3.27	9.26	5.82	9.32
Average	3.81	9.51	5.78	9.69

COMPOSITION OF PEDIGREED CORN.

In order that it might be shown with even more absolute certainty which physical part of the corn kernel should be increased in order to increase the protein content, or the oil content, etc., forty ears of corn were selected from the 1902 crop from our oldest breeding plots, ten ears being taken from each of four different strains, namely:

"Illinois" High Protein Corn.

"Illinois" Low Protein Corn.

"Illinois" High Oil Corn.

"Illinois" Low Oil Corn.

each of which represents the seventh generation of pedigreed corn, bred as indicated by the name. Twenty-five average kernels were taken from each of these forty ears, the germs separated from the remainder of the kernel and both parts (that is, germs and endosperms*) analyzed separately, for each ear, another sample of the corn from each ear also being analyzed to show the composition of the whole corn. The tabular statements show the results obtained.

By referring to Tables 14 and 15 it will be seen that the protein content of the low protein ears varies from 6.36 to 7.09 percent. with an average of 6.71 percent, while the protein content of the high protein ears varies from 13.98 to 15.01, with an average of 14.44 percent. The average oil content of the low protein corn is 4.21 percent and of the high protein ears 4.93 percent. The general averages indicate a slight correlation between oil and protein; however, there are several of the high protein ears which contain less oil than some of the low protein ears, thus showing that such correlation is not constant.

*As here used the term endosperm includes all parts of the kernel except the germ.

TABLE 14.—CHEMICAL COMPOSITION OF TEN EARS OF "ILLINOIS" LOW PROTEIN CORN.

Ear No.	Protein, percent.	Oil, percent.	Ash, percent.	Carbohydrates, percent.
4276	6.98	4.69	1.43	86.90
4281	6.60	4.21	1.33	87.86
4286	6.87	4.16	1.19	87.78
4287	6.37	3.90	1.40	88.33
4295	6.46	4.14	1.15	88.25
4313	7.01	4.13	1.27	87.59
4321	7.09	3.84	1.46	87.61
4328	6.36	4.05	1.43	88.16
4346	6.89	4.33	1.45	87.33
4368	6.48	4.67	1.56	87.29
Average	6.71	4.21	1.37	87.71

TABLE 15.—CHEMICAL COMPOSITION OF TEN EARS OF "ILLINOIS" HIGH PROTEIN CORN.

Ear No.	Protein, percent.	Oil, percent.	Ash, percent.	Carbohydrates, percent.
4174	14.70	5.87	1.48	77.95
4189	14.74	4.46	1.70	79.10
4202	14.21	4.54	1.50	79.75
4212	14.61	4.57	1.66	79.16
4218	14.37	4.61	1.63	79.39
4227	14.03	5.26	1.54	79.17
4242	14.28	5.33	1.51	78.88
4244	14.49	4.71	1.57	79.23
4253	15.01	5.01	1.38	78.60
4265	13.98	4.96	1.67	79.39
Average	14.44	4.93	1.56	79.06

Table 16 shows the percentages of protein and of germ in both the low protein and high protein ears.

TABLE 16.—PROTEIN AND GERM IN LOW PROTEIN AND HIGH PROTEIN CORN.

Low protein corn.			High protein corn.		
Ear No.	Protein, percent.	Germ, percent.	Ear No.	Protein, percent.	Germ, percent.
4276	6.98	9.52	4174	14.70	13.31
4281	6.60	8.81	4189	14.74	9.51
4286	6.87	8.42	4202	14.21	11.44
4287	6.37	9.53	4212	14.61	10.92
4295	6.46	7.95	4218	14.37	11.64
4313	7.01	8.98	4227	14.03	11.15
4321	7.09	10.30	4242	14.28	13.21
4328	6.36	8.88	4244	14.49	11.22
4346	6.89	10.14	4253	15.01	9.82
4368	6.48	10.79	4265	13.98	12.14
Average ...	6.71	9.33	Average ..	14.44	11.44

Here again we see a slight correlation between the average percentages of protein and germ in the corn kernel, although there are noteworthy discrepancies. Thus we have an ear containing 6.37 percent of protein and 9.53 percent of germ, while another ear contains 14.74 percent of protein and 9.51 percent of germ. In other words, the two ears contain practically the same percentage of germ, although one of them contains more than twice as much protein as the other. One of the lowest protein ears (6.48) contains 10.79 percent of germ, while the highest protein ear (15.01 percent) contains only 9.82 percent of germ.

Attention is called to the fact that in selecting seed corn by chemical analysis for high protein there is a tendency to increase not only the horny starchy part (which contains more total protein than any other part of the corn kernel), but also to increase both the horny gluten and the germ, both of which, although small in amount are rich in protein; and consequently there is a slight tendency for the oil to be increased, not only in the germ, but also in the horny gluten (aleurone layer), which it will be remembered is also quite rich in oil. This is the evident explanation as to why there is a slightly higher degree of correlation between oil and protein in our pedigreed strains of corn than there is in ordinary corn which has not been so bred.

Tables 17 and 18 show the percentage composition of the low oil and high oil ears.

TABLE 17.—CHEMICAL COMPOSITION OF TEN EARS OF "ILLINOIS" LOW OIL CORN.

Ear No.	Protein, percent.	Oil, percent.	Ash, percent.	Carbohydrates, percent.
4474	9.40	2.68	1.45	86.47
4486	9.16	2.65	1.64	86.55
4491	9.49	2.60	1.29	86.62
4495	9.57	2.59	1.41	86.43
4509	8.96	2.53	1.36	87.15
4512	10.64	2.45	1.46	85.45
4521	9.97	2.12	1.42	86.49
4537	10.89	2.40	1.54	85.17
4548	9.77	2.54	1.36	86.33
4555	11.92	2.65	1.42	84.01
Average	9.98	2.52	1.44	86.07

The average for the low oil corn is 2.52 percent of oil and 9.98 percent of protein, while the high oil contains 7.00 percent of oil and 11.31 percent of protein. In other words, the high oil corn contains almost three times as much oil as the low oil corn, but is less than one-seventh richer in protein, showing only slight correlation between oil and protein, and with several ears no correlation whatever exists. For example, we have one ear with 10.89 percent of protein and 2.40 percent of oil and another ear with 10.79 percent of protein and 7.01 percent of oil, the protein

being practically equal, while the one ear contains nearly three times as much oil as the other. Again the low oil ear No. 4555 (2.65 percent of oil) contains 11.92 percent of protein, or .61 percent more than the average of all of the high oil ears.

TABLE 18.—CHEMICAL COMPOSITION OF TEN EARS OF "ILLINOIS" HIGH OIL CORN.

Ear No.	Protein, percent.	Oil, percent.	Ash, percent.	Carbohydrates, percent.
4374	11.26	7.10	1.64	80.00
4411	10.79	7.01	1.40	80.80
4412	9.58	6.87	1.58	81.97
4417	10.33	7.01	1.66	81.00
4421	12.55	7.02	1.53	78.90
4423	11.66	6.95	1.56	79.83
4436	11.47	7.17	1.59	79.77
4441	12.94	7.37	1.57	78.12
4448	11.75	6.78	1.52	79.95
4462	10.76	6.74	1.48	81.02
Average	11.31	7.00	1.55	80.14

TABLE 19.—OIL AND GERM IN LOW OIL AND HIGH OIL CORN.

Low oil corn.			High oil corn.		
Ear No.	Oil, percent.	Germ, percent.	Ear No.	Oil, percent.	Germ, percent.
4474	2.68	8.05	4374	7.10	12.90
4486	2.65	8.13	4411	7.01	12.73
4491	2.60	7.92	4412	6.87	13.73
4495	2.59	7.39	4417	7.01	14.50
4509	2.53	7.06	4421	7.02	14.65
4512	2.45	7.89	4423	6.95	13.83
4521	2.12	7.13	4436	7.17	14.10
4537	2.40	7.57	4441	7.37	14.53
4548	2.54	7.83	4448	6.78	14.35
4555	2.65	8.47	4462	6.74	13.03
Average...	2.52	7.74	Average ..	7.00	13.84

Table 19, giving the percentages of oil and germ in the low oil and high oil corn, shows a very marked correlation between oil and germ. The ten low oil ears contain from 2.12 to 2.68 percent of oil (average 2.52) and from 7.06 to 8.47 percent of germ (average 7.74), while the ten high oil ears contain from 6.74 to 7.37 percent of oil (average 7.00), and from 12.73 to 14.65 percent of germ (average 13.84). There is no overlapping and the correlation is very distinct. Every low oil ear contains a small percentage of germ and every high oil ear a high percentage of germ. Attention is called to the fact that the high oil corn is even richer in oil than would be indicated by the high percentage of germ as compared with the percentage of oil and germ in the low oil corn, indicating that the breeding for high oil has not only increased the oil by in-

creasing the percentage of germ (which contains most of the oil), but that the percentage of oil in the germ itself has increased. (Of course there is also an increase in the percentage of oil in the horny glutenous part.) Similarly the percentage of oil has decreased even more rapidly than the percentage of germ in the low oil corn. These results are very apparent in the data shown in Table 20.

EFFECT OF BREEDING ON COMPOSITION OF GERMS AND ENDOSPERMS.

As already explained, ten ears were selected from each of the four different strains of corn (low protein, high protein, low oil, and high oil), and twenty-five kernels were taken from each of these forty ears, the germ being separated from the remainder of the kernel, which we call the endosperm. After the percentage of germ was determined from each individual ear, the germs from each lot of ten ears were put together to make two samples, each sample representing five ears. The endosperms were likewise put together, so that we have duplicate samples of both germs and endosperms for each of the four different strains. These samples were analyzed chemically and the results are given in Table 20.

TABLE 20.—CHEMICAL COMPOSITION OF GERMS AND ENDOSPERMS FROM LOW PROTEIN AND HIGH PROTEIN CORN AND FROM LOW OIL AND HIGH OIL CORN.

Kind of corn.	Part of kernel.	Protein, percent.	Oil, percent.	Ash, percent.	Carbo-hydrates, percent.
Low protein	Germs	{ 18.05	33.59	10.19	38.17
		{ 17.96	34.60	10.16	37.28
High protein	Germs	{ 20.85	34.99	10.12	34.04
		{ 21.65	36.02	10.07	32.26
Low oil	Germs	{ 21.70	25.01	13.13	40.16
		{ 21.71	24.62	13.36	40.31
High oil	Germs	{ 17.55	41.76	8.75	31.94
		{ 17.84	41.75	8.81	31.60
Low protein	Endosperms	{ 5.69	.83	.43	93.05
		{ 5.68	.91	.43	92.98
High protein	Endosperms	{ 13.67	.76	.36	85.21
		{ 13.92	.72	.41	84.95
Low oil	Endosperms	{ 9.13	.52	.47	89.88
		{ 9.14	.51	.43	89.92
High oil	Endosperms	{ 10.62	1.07	.36	87.95
		{ 10.10	1.24	.39	88.27

These results show in a very striking manner the effect of breeding in changing the composition of the different physical parts of the kernel. Thus the germs from the low oil corn contain about 25 percent of oil, while those from the high oil corn contain nearly 42 percent of oil. As

stated above, breeding to change the oil content not only changes the percentage of germ, but it also changes the percentage of oil in the germ. It should also be noted that endosperms from the high oil corn contain more than twice as much oil as those from the low oil corn, although the percentage of oil in the endosperm is very small even in the high oil corn, and this oil is largely contained in the horny gluten.

Perhaps the most marked and valuable results are shown in the percentages of protein contained in the endosperms from low protein and high protein corn; the endosperms from the low protein corn contain less than 6 percent of protein, while those from the high protein corn contain nearly 14 percent of protein. These results, in connection with others which we have given, would seem to prove very conclusively that to select high protein seed corn by mechanical examination we should select principally for a large proportion of the more nitrogenous part of the endosperm; that is, the horny part. To select only for large germs will have only a slight effect upon the protein content of the corn, although it will produce a rapid and marked increase in the oil content.

Referring again to Table 20, it will be seen that the endosperms from the high oil corn contain about one percent more protein than those from the low oil corn. On the other hand, the germs from high oil corn contain less protein (17.7 percent) than those from low oil corn (21.7 percent), the difference being 4 percent protein in favor of the low oil corn.

These results were to be expected even from a study of the analyses of the 163 ears reported in Bulletin No. 55, in 1899, which showed that large germs were naturally even richer in oil than the size of the germs would indicate, and that there is but very slight correlation between oil and protein, the increased oil tending to decrease the percentage, though not the actual amount of protein in the germ. It will be seen from Tables 19 and 20 that the high oil corn contains nearly twice as much germ as the low oil corn, and that the germs from high oil corn are more than one and one-half times richer in oil than the germs from the low oil corn; but that, although the high oil germs contain a larger total amount of protein because of their increased size), they are really considerably poorer in percentage of protein than the low oil germs.

It is perhaps worth while to consider the evident fact that, even if the protein should increase in the germ in the same proportion as the oil (which is not the case), we should need to increase the oil two pounds for every one pound increase in protein obtained, if we depend upon the method of picking our high protein seed corn by selecting for large germs. In other words, to increase the protein in corn from 10 percent to 15 percent by this method, would require the oil in the corn to be increased from 5 percent to 15 percent.

Although we do not assume to say what should be the percentage of oil in corn for feeding purposes, we do take the liberty of raising the ques-

tion whether the popular opinion that the oil in corn should be increased for feeding purposes may not be erroneous. Certainly the investigations of Lehmann in Germany and of Shutt in Canada have indicated very strongly that corn is already too rich in oil to be suitable as a foodstuff for bacon hogs. It may also be called to mind that some other excellent foodstuffs, such as oats, bran, barley, red clover and alfalfa, contain less than half as much oil as is already contained in ordinary corn.

Attention is called to the fact that although the physical parts of the corn kernel which contain nearly all of the oil (namely the germ and the horny gluten) also contain most of the ash, yet a high percentage of ash in the germs is associated with a low percentage of oil, and *vice versa*, indicating that the ash content of the germ (which includes the major part of the ash of the entire kernel) bears a more constant relation to the oil-free material in the germ than to the whole germ. By computation we find that the oil-free germs contain the percentages of ash given in Table 21 (assuming the oil to contain no ash, which is approximately correct*).

TABLE 21.—PERCENTAGE OF ASH IN GERMS.

	In fresh germs.	In oil-free germs.
From low protein corn	{ 10.19 10.16	15.34 15.54
From high protein corn	{ 10.12 10.07	15.57 15.74
From low oil corn	{ 13.13 13.36	17.51 17.72
From high oil corn	{ 8.75 8.81	15.02 15.12

Breeding for high or low protein produces no marked effect upon the ash content or the oil content of either the germs or the endosperms, and only slightly influences the protein content of the germs. (The low protein germs contain about 18 percent of protein and the high protein germs about 21 percent.) The results show that such breeding produces exceedingly marked effects upon the protein content of the endosperms, the low protein endosperms containing less than 6 percent and the high protein endosperms nearly 14 percent of protein. In this connection it is well to remember that the corn kernel usually contains only about 11 percent of germ, while the endosperm amounts to about 89 percent of the kernel. The significance of this becomes more readily apparent by an examination of Table 22, which shows where the protein actually exists in 100 pounds of corn.

*Actual determinations of the ash in corn oil have shown that the oil contains only 0.2 per cent of ash.

TABLE 22.—PROTEIN IN 100 POUNDS OF CORN.

Names of parts.	Low protein corn.			High protein corn.			Difference.
	Percent of corn.	Percent of protein.	Pounds of protein.	Percent of corn.	Percent of protein.	Pounds of protein.	Pounds of protein.
In germs	9.33	18.01	1.68	11.44	21.25	2.43	.75
In endosperms	90.67	5.69	5.16	88.56	13.80	12.22	7.06

We thus find as a result of corn breeding that in the seventh generation we have a maximum difference of only .75 pound of protein in the germs from 100 pounds of low protein and high protein corn, while in the endosperms from these two kinds of corn we have a difference of 7.06 pounds of protein, in 100 pounds of corn. In other words, in changing the protein content of corn the effect produced in the endosperms amounts to almost ten times the effect produced in the germs.

THE COMPOSITION OF HOMINY MILL PRODUCTS.

Besides the investigations which we have carried on along this particular line in connection with our work of corn breeding, we have also made some study of factory products, especially the products from hominy mills, which make use of immense quantities of corn.

In the regular process of milling corn, a very large number of separations are made and several distinctly different final products are obtained, some of which are composed almost entirely of certain distinct physical parts of the corn kernel. The following is a brief and very general description of the usual process of corn milling:

The whole corn is somewhat softened by steaming and is then run through a hulling machine, which not only removes the hull, but loosens the germ and breaks off the horny gluten and more or less white starch. The dust or pulverized material coming from the hulling machine consists largely of white starch and horny gluten. The hulls and germs are each separated but not in very pure condition, leaving what is termed hominy, which consists chiefly of the horny starchy part of the kernel, with more or less adhering white starch.

The product which is known as grits is made from the hominy and consists of the horny starchy part separated in very pure form. In making grits the coarse hominy is run through a grinding machine and reduced to a coarse powder which may be termed coarse grits, much of the adhering white starch being rubbed off from the horny starch in this process. The coarse grits are then run through one or two more grinding machines, until the horny starch is reduced to a rather fine powder, which may be termed fine grits. This material consists of the horny starch in very pure condition. After each grinding the fine dust consisting largely

of the white starch is separated from the grits and goes into the product known as corn flour.

In addition to the corn flour thus regularly separated and handled in considerable quantities, there is constantly produced a small amount of what is termed "break" flour. This is an exceedingly fine dust also produced in the process of breaking the corn particles in the grinding machines which reduce the hominy to grits. The break flour is carried from the machine by an air current through conduits and finally collected. This is another very pure form of the white starch.

Thus, in the regular milling process there are two physical parts of the corn kernel separated in very pure form: namely, horny starch (fine grits) and white starch (break flour or corn flour) and two other distinct parts which are separated somewhat less perfectly, the hulls and the germs.

By the courtesy of the manager of the American Hominy Company's Mills at Decatur we were allowed to collect representative samples of these different products for analysis. The composition of these products is given in Table 23, and it will be found interesting to compare these results with the composition of the same products, or parts, which were obtained by exact hand separation, as given in Table 1. For convenience in comparison Table 23 also shows the composition of these parts as obtained from Ear No. 1 (Table 1), which is very similar to the corn which was being used in the mill at the time the samples were taken. This was fairly representative of the ordinary white corn grown in 1902, nearly all of which was abnormally low in protein, owing to seasonal influences.

TABLE 23.—COMPOSITION OF PARTS OF THE CORN KERNEL SEPARATED BY HOMINY MILL AND BY HAND.

Names of parts.	Methods of separation.	Protein, percent.	Oil, percent.	Ash, percent.	Carbo-hydrates, percent.
Hulls	By mill	6.85	2.94	1.11	89.10
Hulls	By hand	4.97	.92	.82	93.29
Horny starch (fine grits) ..	By mill	8.46	.44	.26	90.84
Horny starch	By hand	8.12	.16	.18	91.54
White starch (corn flour*) ..	By mill	5.91	1.63	.49	91.97
White starch (break flour)	By mill	5.88	2.04	.68	91.40
White starch (from tip)...	By hand	6.10	.29	.29	93.31
Germs	By mill	15.84	21.26	7.41	55.49
Germs	By hand	19.91	36.54	10.48	33.07
Whole corn.....	Mill sample	9.31	4.20	1.43	85.06
Whole corn.....	Ear No. 1	9.28	4.20	1.41	85.11

*Obtained by direct separation from grits.

In general the composition of these mill separations agrees with the composition of the same parts separated by hand, although in nearly all cases the mill products show more or less contamination or mixture with other parts of the kernel. Thus the mill hulls are noticeably high in protein and oil owing to the presence of some particles of horny gluten and germ; while the mill germs are too low in protein and oil because of the presence of some hulls and tip caps. Furthermore, some oil is lost from the germ and absorbed by other parts in the milling process. The fine grits are almost pure horny starch, except that they contain about twice as much oil as the hand-separated product. This is doubtless due to the fact that some germs are broken or crushed in the hulling machine and the liberated oil is absorbed to some extent by the hominy, chiefly, of course, by the white starch, as indicated by the high oil content of the break flour and the other regularly separated corn flour, although it is evident that a small portion of this liberated oil remains adhering to the fine grits. The white starch contains 5.88 to 5.91 percent of protein, while the horny starch (fine grits) contains 8.46 percent, or almost one-half more.

It will be observed that the two samples of whole corn are almost identical in composition. While the corn is fairly representative of much of the white corn grown during the season of 1902, attention is called to the apparent fact that this is not the most suitable corn for the manufacture of hominy and grits. It seems evident that corn containing a higher percentage of the horny starchy part would be more valuable for the hominy mill. The manager of the American Hominy Company's Mills at Decatur has assured the writer that he prefers corn which shall run high in grits (horny starch), but he does not desire that the oil content should be increased; indeed, it would be much better for milling purposes to have the percentage of oil in corn reduced, because of the difficulty of preventing the oil from being absorbed by other products and injuring their quality, the tendency being for the oil to become rancid when exposed to the air. The hominy mills offer some encouragement to farmers to grow corn especially suited to their use.

SUMMARY OF BULLETIN No. 87.

The investigations reported in this bulletin serve to establish the following facts:

1. The kernel of corn consists of six readily observable and distinctly different physical parts, which are known as (1) the tip cap, (2) the hull (3) the horny gluten, (4) the horny starch, (5) the white starch, (6) the germ.
2. The tip cap covers the tip or base of the kernel and comprises only about 1.5 percent of the grain.
3. The hull is the very thin outer coat. It comprises about 6 percent

of the kernel and contains a lower percentage of protein (about 4 percent) than any other part of the kernel.

4. The horny glutenous part (aleurone layer) lies underneath the hull surrounding the kernel. It comprises from 8 to 14 percent of the grain (being more abundant in high protein corn), and it contains from 20 to 25 percent of protein, being the richest in protein of all the parts of the corn kernel.

5. The horny starchy part is the chief substance in the sides and back of the kernel (the germ face being considered the front of the kernel). This substance comprises about 45 percent of ordinary corn, but is much more abundant in high protein corn and less abundant in low protein. Although rich in starch it contains about 10 percent of protein (more in the high protein corn and less in low protein corn). It contains a greater total amount of protein than any other part of the kernel.

6. The white starchy part occupies the center of the crown end of the kernel and usually partially surrounds the germ. It comprises about 25 percent of the kernel (less in high protein corn and more in low protein corn). It is poor in protein (5 to 8 percent).

7. The germ occupies the central part of the kernel toward the tip end. It comprises about 11 per cent of the kernel (more in high oil corn and less in low oil corn). The germ contains from 35 to 40 percent of corn oil or from 80 to 85 percent of the total oil content of the corn kernel.

8. High protein corn contains a large proportion of the horny parts (both of the horny glutenous part and the horny starchy part), and a correspondingly smaller proportion of the white starchy part. The horny parts comprise more than 60 percent of high protein corn and contain about 80 percent of the total protein content of very high protein corn.

9. The value and reliability of the method proposed in previous bulletins by which any farmer can select high protein seed corn (selecting for a large proportion of horny parts) by a simple mechanical examination of the corn kernels has been fully confirmed by the results which have been subsequently obtained and which are now reported in this bulletin.

10. The value of the method proposed for picking out high oil seed corn by selecting for a large proportion of germ is also fully established.

11. The degree of correlation existing in the corn kernel between the percentages of germ and protein is very slight and is frequently entirely absent, consequently the proportion of germ in the corn kernel is not a reliable index of its protein content.

12. The composition of the different products obtained from corn by hominy mills, as well as by other factories, serves greatly to emphasize the importance of breeding corn for special purposes.

(For more complete details of corn breeding, the reader is referred to Bulletin No. 82, "Methods of Corn Breeding," which can be obtained upon

request from the Illinois Experiment Station, Urbana, Illinois. The supply of Bulletin No. 53 and Bulletin No. 55, both relating to corn investigations, is now exhausted.)

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

URBANA, AUGUST, 1903.



BULLETIN No. 88.

SOIL TREATMENT FOR WHEAT IN ROTATIONS, WITH SPECIAL REFERENCE TO SOUTHERN ILLINOIS SOILS.

BY CYRIL G. HOPKINS, PH. D., CHIEF IN AGRONOMY AND CHEMISTRY.

In connection with the investigation of Illinois soils, the University of Illinois is conducting soil experiment fields on the most important types of soil in different sections of the state. The object of these experiments is to determine the best methods of soil treatment and the most suitable rotations for maintaining and increasing the productive capacity of Illinois soils. These soil experiment fields have been in operation only two years, but some results already obtained are so suggestive that it is believed they will be of value to the farmers and land owners of Illinois, and for that reason this preliminary bulletin is published at this time, giving results obtained with various kinds of soil treatment for wheat grown in rotations. It should be definitely understood that the soil treatment and rotations which we are trying must be followed for six or eight years at least before final conclusions can be drawn, whereas we have obtained only two years' results, not having had time as yet to complete even a three-year rotation.

PLAN OF EXPERIMENTS.

The plan of the rotations which we have adopted includes a liberal use of legumes (clover, cow peas, soy beans, vetch, etc.), both as catch crops and as regular crops in the rotation, but the 1902 crops were the first we have grown upon these soil experiment fields, and, of course, the wheat grown that year preceded the leguminous catch crops and received no benefit from them. In 1903 the wheat on certain plots followed either a regular crop or a catch crop of legumes, grown in 1902.

Our regular three-year rotation is as follows:

First year—Corn or wheat (with a legume catch crop on certain plots).

Second year—Oats (with a legume catch crop on the same plots as in the first year).

Third year—Legume (clover, cow peas, or some other legume).

All legume catch crops are plowed under for the benefit of the land. (Wherever practicable they may be pastured off.)

For a catch crop with corn, cow peas or soy beans are seeded between the rows when the corn is laid by, about the first of July; or winter vetch may be seeded with the cow peas or soy beans or it may be seeded alone when the corn is laid by, or at any time during July or August. The cow peas or soy beans usually grow rapidly until frost, while the vetch grows much more slowly at first, but continues to grow during the fall and again the next spring. In favorable seasons clover may be seeded in the corn when it is laid by to serve as a catch crop.

For a catch crop with wheat or oats, clover may be seeded in the spring or cow peas, soy beans, or winter vetch may be seeded as soon as possible after the wheat or oats is harvested, the stubble ground being either disked or preferably plowed, before seeding the catch crop.

The regular legume crop is usually all harvested and removed from the land, but on land which is very deficient in nitrogen this full crop of legumes may be plowed under on the same plots upon which legume catch crops are grown.

A regular four-year rotation may be:

Corn, corn, oats and legume, or
corn, oats, wheat and legume, or
wheat, wheat, oats and legume.

A five-year rotation would be the same as a four-year rotation except that it would include one more crop of corn or wheat, or one of timothy.

In all rotations certain plots are seeded with legume catch crops every year. When a legume catch crop is grown or when the regular full crop of legumes on any plot is plowed under, it is termed "legume treatment." It is not called "legume treatment" when a full crop of legumes is grown and the entire crop removed from the land, as is usually done one year in all rotations.

Where lime is applied the amount used is governed by the need of the soil as ascertained by a determination of the soil acidity. On some soils the first application must be heavy, sometimes amounting to several tons, but afterward an application of 1,000 or 2,000 pounds once in six or eight years will probably be sufficient to keep the soil sweet.

Where phosphorus is applied, the regular plan is to apply 400 pounds of fine ground steamed bone meal the first year and afterwards 200 pounds a year. (On some fields, instead of 400 or 200 pounds of bone meal, we use 1,000 or 500 pounds, respectively, of ground rock phosphate.)

Where potassium is applied, the plan is to apply 200 pounds of potassium chlorid ("muriate" of potash), or 200 pounds of potassium sulfate the first year, and afterward 100 pounds a year.

On some of the fields, farm manure is also applied to certain plots, not only alone, but also in various combinations with other fertilizers. Where manure is applied, the regular plan is to apply it at the rate of two tons per acre per annum, but it is applied only once in a rotation. Thus, in a three-year rotation of corn, oats, and clover the manure would be applied at the rate of six tons per acre for the corn crop only. In a four-year rotation, eight tons per acre would be applied once in four years.

Attention is called to the fact that in considering yields from field experiments some allowance must be made for the natural variation which may exist between different plots. Very great care was taken in locating these soil experiment fields to select uniform land and our regular rule is to use the best land for the check plots (plots with no treatment) in case there is any indication of soil variation in the field. This is done in order that the results obtained by soil treatment shall not be exaggerated.

In this connection I have great pleasure in expressing my sincere appreciation of the faithful care and patience of the progressive farmers upon whose farms our soil experiment fields are located, who have had immediate charge of the regular work in carrying on these soil experiments. Their names are mentioned in connection with the descriptions of the individual fields.

Especial credit is due to my field assistant in soil experiments, Mr. J. E. Readhimer, who has superintended all of these fields, and has taken immediate charge of all operations not included in ordinary farm work, such as applying the different elements of plant food to the proper individual plots, taking exact yields of crops produced, and other unusual work.

(For more complete information regarding the different elements of plant food, the amounts required by different crops, and the purchase, use, and application of fertilizers, and for descriptions of the different soil areas in the state, the reader is referred to Illinois Experiment Station Circular No. 68, "Methods of Maintaining the Productive Capacity of Illinois Soils," which will be sent upon request to any farmer or land owner in the state.)

VIENNA SOIL EXPERIMENT FIELD.

This experiment field is located in the N. E. 10, N. E. 40, N. E. $\frac{1}{4}$, Sec. 9, Twp. 13 S., R. 3 E. of 3d P. M., on the farm of Mr. J.M. Price, near Vienna, Johnson County, on soil which is believed to be fairly representative of the common so-called "red clay" hill soil, the principal type in the unglaciated area, which includes the seven southernmost counties in the state.

This experiment field consists of fifteen fifth-acre plots arranged in three series of five plots each, numbered from 1 to 5.

The rotation for this field is:

First Year—Corn or wheat (with a legume catch crop on plots 2, 3, 4, and 5).

Second Year—Oats (with a legume catch crop on plots 2, 3, 4, and 5).

Third Year.—Legume (clover, cow peas, soy beans, or some other legume).

All regular crops in the rotation are grown every year; thus, one series of five plots may grow wheat, the next series oats, and the third series cow peas. The following year wheat would follow the cow peas, oats follow the wheat, and cow peas would be seeded on the series which had grown oats. Thus every crop is grown every year, which would not be the case if we made use of only one series of plots growing wheat one year, oats the next, and cow peas the next. The soil treatment is the same for each series. Plot No. 1 (in each series) receives no soil treatment, plot No. 2 receives the legume treatment; plot No. 3 legume treatment and lime; plot No. 4 legume treatment with lime and phosphorus; and plot No. 5 legume treatment with lime, phosphorus, and potassium. Thus lime is applied to plots 3, 4, and 5; phosphorus to plots 4 and 5; and potassium is applied to plot 5 only.

Wheat was not grown on the Vienna field in 1902, but in 1903 it was grown on one series of five plots. These plots had grown a regular crop of cow peas in 1902 and on plots 2, 3, 4, and 5, this legume crop had been plowed under.

Table 1 shows the kinds of treatment applied to the different plots and the yields of wheat obtained in 1903.

TABLE 1.—CROP YIELDS IN SOIL EXPERIMENTS; VIENNA FIELD.

Soil plot No.	Soil treatment applied* to "Red Clay" hill soil of the unglaciated area.	Bushels per acre, wheat, 1903
1	None	0.4†
2	Legume	0.5†
3	Legume, lime	0.7†
4	Legume, lime, phosphorus	8.0
5	Legume, lime, phosphorus, potassium	11.0

* Only a part of the lime was applied before growing the 1902 crop; the rest after that crop was harvested.

† The yields for these three plots were estimated (see Table 2).

The wheat was practically a total failure on the three plots which had received no phosphorus, although a crop of legumes had been turned under on plot 2 and legumes with lime on plot 3.

Plot 4 which received phosphorus, with legume treatment and lime, yielded eight bushels per acre; and plot 5, which received legume treatment with lime, phosphorus, and potassium, yielded eleven bushels.

Of course the season was considered exceptionally unfavorable for wheat, otherwise a small crop at least would have been obtained on the untreated plot. Many large fields of wheat in the vicinity of Vienna were practically failures, several farmers reporting yields no greater than the seed which had been sown.

ODIN SOIL EXPERIMENT FIELD.

This experiment field is located chiefly in the S. W. 40, S. W. $\frac{1}{4}$, Sec. 14, Twp. 2 N., R. 1 E. of 3d P. M., on the farm of Col. N. B. Morrison, near Odin, Marion County, on the ordinary gray silt soil (commonly called "white clay" soil) of the lower Illinoisan glaciation, a soil area which includes more or less of about twenty-five counties in South Central Illinois.

This experiment field consists of forty fifth-acre plots arranged in four series of ten plots each, five of each series of ten plots being tile-drained and the other five not tile-drained. (Four-inch tile are laid about three and a half feet deep and five rods apart, one string through the center of each drained plot.)

Wheat was not grown on this field in 1902, but in 1903 it was grown in the one series upon plots which had grown oats in 1902, the oats having been followed by a catch crop of cow peas on certain plots as indicated in Table 2, which shows the kinds of treatment applied to the different plots and the yields of oats obtained in 1902 and of wheat obtained in 1903.

TABLE 2.—CROP YIELDS IN SOIL EXPERIMENTS; ODIN FIELD.

OATS, 1902.			
Soil plot No.	Soil treatment applied * to gray silt soil of the lower Illinois glaciation.	Bushels per acre.	
		Not tile-drained.	Tile-drained.
1	None	15.8	12.2
2	Legume	16.1	10.3
3	Legume, lime	14.1	11.7
4	Legume, lime, phosphorus	16.7	19.2
5	Legume, lime, phosphorus, potassium	18.8	17.7
WHEAT, 1903.			
1	None	0.4†	0.5†
2	Legume	0.5†	0.6†
3	Legume, lime	0.7†	2.1†
4	Legume, lime, phosphorus	5.8	13.4
5	Legume, lime, phosphorus, potassium	14.0	15.2

* The legume treatment applies only to the crop yields for 1903, and only a part of the lime was applied before the 1902 crop was grown.

† The sheaves, or bundles, from each of these six very low yielding plots were counted separately, but the wheat from the six plots was all threshed as onelot, and the weights then apportioned among the different plots as indicated by the number of bundles. The yields from the first three lots on the Vienna Field were estimated to be the same as from the corresponding untilled Odin plots. All other yields given are actual weights.



PLATE 1.—WHEAT CROP WITH NO TREATMENT: ODIN SOIL EXPERIMENT FIELD.

Plates 1, 2, and 3 show the condition of several of the wheat plots just before they were harvested.

Plate 1 is from a photograph of the tile-drained plot No. 1, which had



PLATE 2.—WHEAT CROP WITH LEGUME AND LIME TREATMENT: ODIN SOIL EXPERIMENT FIELD.



PLATE 3.—WHEAT CROP WITH LEGUME, LIME, AND PHOSPHORUS TREATMENT:
ODIN SOIL EXPERIMENT FIELD.

received no special soil treatment and which yielded 0.5 bushels of wheat per acre.

Plate 2 shows the condition of the wheat on the tile-drained plot No. 3 which received lime and on which a catch crop of cow peas had been turned under. It yielded 2.1 bushels of wheat per acre.

Plate 3 shows the wheat on the tile-drained plot No. 4, which received lime, phosphorus and legume treatment. It yielded 13.4 bushels of wheat, or 11.3 bushels more than plot No. 3, the increase apparently due to the application of phosphorus.

It will be observed that the tile-drained plot No. 4 (legume, lime, phosphorus), produced a noticeably higher yield of both oats and wheat than the corresponding undrained plot, the difference in yield being 2.5 bushels of oats and 7.6 bushels of wheat in favor of the drained plot. On the other hand, on the first three plots the tile-drained land gives smaller yields of oats and only slightly larger yields of wheat than the undrained land.

CUTLER SOIL EXPERIMENT FIELD.

This experiment field is located chiefly in the N. 20, S. E. 40, N. W. $\frac{1}{4}$, Sec. 19, Twp. 5 S., R. 4 W. of 3d P. M., on the farm of Mr. W. E. Braden about five miles northwest of Cutler, on the line between Perry and Randolph counties, on the so-called "white clay"* (gray silt) soil of the lower

* This soil is not clay, but largely silt. It might be called a *gray silt loam*; it is a fine friable powder (finer than sand); but it is not plastic clay.

Illinoisan glaciation, but the soil at Cutler is perhaps a slightly better phase of this type than that at Odin.

The rotation experiments occupy thirty fifth-acre plots arranged in three divisions of ten plots each. Wheat was grown on ten plots in 1902. The results obtained are given in Table 3.

TABLE 3.—CROP YIELDS IN SOIL EXPERIMENTS; CUTLER FIELD

Soil plot No.	Soil treatment applied to gray silt soil in the lower Illinoisan glaciation.	Bushels per acre, wheat, 1902.
1	None	12.8
2	None	12.4
3	None	12.4
4	None	13.3
5	None	12.9
6	Phosphorus	16.9
7	Phosphorus	16.1
8	Phosphorus, potassium	20.8
9	Phosphorus, potassium	19.4
10	Phosphorus, potassium	20.8

In 1903 wheat was grown on ten plots which had grown a regular crop of cow peas in 1902. On plots 2, 4, 6, and 8 the cow peas were turned under ("legume treatment"); but on the other plots the crop of cow peas was harvested and removed. On plots 3, 5, 7, and 9 an application of farm manure was made to the cow-pea stubble ground, which was then plowed for wheat. Table 4 shows the results obtained in 1903.

TABLE 4.—CROP YIELDS IN SOIL EXPERIMENTS; CUTLER FIELD.

Soil plot No.	Soil treatment applied to gray silt soil in the lower Illinoisan glaciation.	Bushels per acre, wheat, 1903
1	None	6.0
2	Legume	9.2
3	Manure	12.1
4	Legume, lime	13.5
5	Manure, lime	13.3
6	Legume, lime, phosphorus	20.3
7	Manure, lime, phosphorus	20.8
8	Legume, lime, phosphorus, potassium	26.8
9	Manure, lime, phosphorus, potassium	24.0
10	Lime, phosphorus, potassium	21.1

The yields of wheat obtained from the crops of 1902 and 1903 on the Cutler experiment field certainly show very markedly the effect of applications of plant food.

In 1902 there were five plots which received no treatment and the yields from those five plots were exceedingly uniform, varying from 12.4 to 13.3 bushels. Phosphorus gave an increase of about 4 bushels, and both phosphorus and potassium an increase of about eight bushels, above the yields from the untreated plots.

In 1903 the yield on the untreated plot was six bushels. Where cow peas had been turned under the yield was increased by 3.2 bushels, and where lime was applied and cow peas turned under the increase was 7.5 bushels over the untreated plot, making a yield of 13.5 bushels. Legume, lime, and phosphorus gave a yield of 20.3 bushels, an increase of 14.3 bushels over the untreated plot; and with legume, lime, phosphorus, and potassium the total yield was 26.8 bushels of wheat, making a net increase of 20.8 bushels over the untreated plot.

Manure produced almost the same effect as turning under cow peas, except that when no other treatment was added the manure gave 2.9 bushels better yield than the legume treatment, whereas, when all other treatments were added (plots 208 and 209), the legume gave 2.8 bushels better yield than the manure.

Where lime, phosphorus, and potassium were applied without legume or manure (plot 210) the yield was 21.1 bushels, which is 15.1 bushels more than the untreated plot, but 5.7 bushels less than where cow peas were turned under, and 2.9 bushels less than where manure was used with applications of lime, phosphorus and potassium.

It is probable that the legume supplies more nitrogen (gathered from the air) than the manure, but the manure adds to the soil a small amount of phosphorus and a considerable quantity of potassium, while the legume supplies no phosphorus or potassium except what it takes from the soil in growing.



PLATE 4.—WHEAT CROP WITH NO TREATMENT: CUTLER SOIL EXPERIMENT FIELD.

Plate 4 shows the wheat crop on the untreated plot No. 1; and Plate 5 shows plot No. 6 (legume, lime, phosphorus) on the left, and plot No. 7 (manure, lime, phosphorus) on the right; also in the center, between the plots, an untreated half-rod division strip.

MASCOUTAH SOIL EXPERIMENT FIELD.

This experiment field is located in the S. 20, S. W. 40, S. E. $\frac{1}{4}$, Sec. 17, Twp. 1 N., R. 6 W. of 3d P. M., on the farm of Mr. George Postel (operated by Mr. John A. Rumer), about three miles north of Mascoutah, St. Clair County, on the brown silt soil of the middle Illinoian glaciation.

This soil in St. Clair County is evidently a somewhat lighter phase of the type than is found farther north. (This is the principal type of soil in Sangamon and adjoining counties, but in St. Clair County the soil is somewhat older and more worn.)

The rotation experiments on this field occupy forty tenth-acre plots, arranged in four series of ten plots each. The rotation followed thus far is corn, oats, wheat, and cow peas, with legume catch crops on certain plots with or after the corn, oats, and wheat.



PLATE 5.— WHEAT CROP WITH NO TREATMENT IN THE CENTER, WITH LEGUME, LIME, PHOSPHORUS ON THE LEFT, AND WITH MANURE, LIME, PHOSPHORUS ON THE RIGHT: CUTLER SOIL EXPERIMENT FIELD.

In 1902, the results obtained with wheat were as shown in Table 5.

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS; MASCOUTAH FIELD.

Soil plot No.	Soil treatment applied* to brown silt soil of the middle Illinoisan glaciation.	Bushels per acre, wheat, 1902.
1	None	19.7
2	None	15.2
3	None	15.3
4	Lime.....	17.7
5	Lime.....	16.5
6	Lime, phosphorus.....	24.7
7	Lime, phosphorus.....	28.0
8	Lime, phosphorus, potassium.....	29.8
9	Lime, phosphorus, potassium.....	31.7
10	Lime, phosphorus, potassium.....	39.8

* Only part of the lime was applied before growing the 1902 crop.

These results show very markedly the effect of phosphorus, the yield of wheat having been increased by that element from about sixteen bushels to twenty-six bushels. Where potassium was applied there was a farther increase, but the results are quite discordant from plots treated alike, indicating some soil differences.

In 1903 wheat was grown on plots which had grown oats in 1902, a catch crop of cow peas (seeded on the stubble ground), having been grown after the oats on certain plots ("legume treatment"). The ground was plowed for wheat about September 20, 1902, and the wheat seeded soon afterward. The weather conditions which followed proved very unfavorable for wheat seeded on late plowing, and the early seeded wheat was badly injured by the Hessian fly; consequently the 1903 wheat crop on these plots was practically a failure—very much poorer than on adjoining land which had been plowed early in the fall. The results obtained are of little value and if not understood would be misleading as to the effect of the different kinds of soil treatment. Table 6 gives the yields of oats in 1902, and of wheat in 1903, obtained on these plots.

TABLE 6.—CROP YIELDS IN SOIL EXPERIMENTS; MASCOUTAH FIELD.

Soil plot No.	Soil treatment applied* to brown silt loam of the middle Illinoisan glaciation.	Bushels per acre.	
		Oats, 1902.	Wheat, 1903.
1	None	31.6	4.7
2	Legume	37.2	5.0
3	None	41.6	4.8
4	Legume, lime	43.8	7.5
5	Lime.....	45.0	4.3
6	Legume, lime, phosphorus	46.9	10.5
7	Lime, phosphorus.....	46.3	4.7
8	Legume, lime, phosphorus, potassium.....	50.6	8.0
9	Lime, phosphorus, potassium	54.1	6.5
10	Lime, phosphorus, potassium	57.8	7.4

* Only part of the lime was applied before growing the 1902 crop, and the legume treatment applies only to the 1903 crop yields.

Of course no conclusions regarding soil treatment can be drawn from the 1903 wheat yields on these plots, unless possibly that there is an indication of some slight benefit from the "legume" treatment, especially in connection with phosphorus.

GENERAL DISCUSSION OF RESULTS.

The tables in the foregoing pages give all of the results which we have obtained in 1902 and 1903, with different kinds of soil treatment for wheat grown in rotations upon the regular University soil experiment fields, located in different sections of southern Illinois. They show some discrepancies which are not explained by the differences in soil treatment, but which may be due to variations in the original condition of the different plots, or in some cases, possibly to differences in the amount of injury caused by the Hessian fly, chinch bug or other insects, which cannot usually be ascertained with accuracy. With the exception of the very poor 1903 wheat crop on the Mascoutah field, the results in general are a trustworthy index of the effect of the soil treatment.

The Cutler field is on very uniform soil and the results obtained on that field may well serve as the basis for a general discussion of the effects of soil treatment. While the results in 1902 were much more marked on the Mascoutah field, they were more discordant and relatively less reliable than those at Cutler. The Cutler field includes practically the same kinds of experiments which have been conducted at Vienna, at Odin, and at Mascoutah; and, in addition, the manure treatment was applied at Cutler for the 1903 wheat crop.

During the two years about three tons of slacked lime, 600 pounds of bone meal (containing about 13 percent of phosphorus, or seventy-eight pounds of that element), and 300 pounds of potassium sulfate* (containing about 40 percent of potassium, or 120 pounds of that element) have been applied per acre on the proper plots at Cutler. On certain plots sixteen tons of farm manure were applied per acre in the fall of 1902. (This was a heavier application than it was intended to have applied, twelve tons being sufficient for six years, or six tons for three years, on the basis that two tons of manure per acre per annum is as much manure as a stock farmer can produce from the crops grown on his own farm.) Cow peas were grown in 1902, and on certain plots the entire crop was plowed under in the fall.

It is not expected that it will be necessary to apply any more lime for at least five years, and after that time probably 1,000 pounds of lime per acre once in five to ten years will be sufficient to keep the soil free from acidity and in suitable condition for growing legumes. After we have grown a legume catch crop for one rotation we do not expect to plow under the regular legume crop on any of the plots, but to depend upon the

*The chlorid was used one year in place of the sulfate.

legume catch crop, and the stubble and roots of the legume used in the regular rotation, to maintain the supply of nitrogen.

The question naturally and necessarily arises whether any of these different kinds of soil treatment will prove to be profitable; and, if so, which treatment is likely to be the most profitable. While the experiments have been in progress only two years and of course no final conclusions can be drawn, yet some computations can easily be made which may be of value even though they are somewhat tentative.

The yield of wheat on the untreated plot was six bushels per acre. At 60 cents a bushel this amounts to \$3.60. Assuming the farm to be worth \$40 an acre, the investment at 5 percent would require \$2.00 to pay the interest. This would leave a balance of \$1.60 an acre to pay for raising the wheat. But even this amount, \$1.60, is too high, unless the soil which grows the crop contains an unfailing supply of plant food, which is certainly not the case with the principal type of soil in the lower Illinoisan glaciation. By reference to Table 1, page 4, of our Circular No. 68, "Methods of Maintaining the Productive Capacity of Illinois Soils" (which will be sent upon request to any Illinois farmer or land owner), it will be seen that a six-bushel crop of wheat would remove from the soil about ten pounds of nitrogen, one and two-thirds pounds of phosphorus and seven pounds of potassium. That these elements of plant food actually possesses an agricultural value in this soil is well demonstrated by the crop yields from this field as shown in Tables 3 and 4. For example, we have applied during the two years 600 pounds of bone meal per acre to certain plots on this field. The bone meal contains 13 percent of the element phosphorus, or thirteen pounds per hundred, making a total of seventy-eight pounds of phosphorus applied. The first year phosphorus increased the yield of wheat from 12.8 bushels to 16.5 bushels, making an increase of 3.7 bushels of wheat. The second year the phosphorus increased the yield from 13.4 to 20.6 bushels, or 7.2 bushels increase, making a total increase of 10.9 bushels for the two years. At 60 cents a bushel, this increase of 10.9 bushels would have a value of \$6.54. Dividing this amount by seventy-eight we find that the phosphorus has already paid back in wheat more than eight cents a pound for every pound applied. When we bear in mind that the increase of 10.9 bushels has removed from the soil only three pounds of phosphorus and that we have seventy-five pounds of the phosphorus applied still left in the soil to benefit succeeding crops, we can then appreciate the fact that phosphorus has an agricultural value in this soil.

Now, what is the value of these different elements of plant food, nitrogen, phosphorus, and potassium? They may be valued in two different ways.

First. They have a commercial value. The commercial value is what it costs to get them.

Second. They have an agricultural value. The agricultural value is measured by the increased crop yields which they give when applied to the soil.

These two different values are almost independent of each other. The commercial value varies with the cost of preparation, grinding, transportation, etc., while the agricultural value varies with the character and composition of the soil to which the plant food is applied, also with the kind of crop to be grown.

To illustrate, dried blood, which contains 14 percent of nitrogen, costs about \$42 a ton, wholesale in Chicago. Thus, 280 pounds of the element nitrogen bought in this form would cost \$42, or 15 cents a pound; and this is the commercial value of nitrogen in dried blood. The nitrogen in dried blood is practically all available for the use of plants.

We have applied dried blood on several soil experiment fields located on various types of soil in different sections of Illinois. While our data are not yet sufficient to warrant final conclusions, I may say that thus far the results from these field experiments have given the nitrogen in dried blood an agricultural value varying from zero to about 2 cents a pound, measured by the increase in crop yields produced.

By reference to Table 6, page 24, of Circular 68, it will be seen that the results of ten years' investigations by the Ohio Experiment Station show the agricultural value of nitrogen applied to be from 1.2 cents to 9.1 cents a pound, while the cost or commercial value was at least 15 cents a pound.

All of these results refer to the use of commercial nitrogen in general farming. Of course, in market gardening or in other intensive farming upon land of very high value, and where crops of high value are produced on an acre of land, and especially in the forcing of early vegetables in order to obtain the highest price in the early part of the season, the agricultural value of nitrogen may sometimes amount to many times its cost. Such lands are usually far too valuable to give them up to the growing of legumes even for a part of the season.

The New Jersey Experiment Station has recently shown that the application of 300 pounds of nitrate of soda per acre, costing \$6.75, increased the value of the celery crop from \$118.30 to \$381.90 per acre. This was due in part to increased yield, but much more largely to improvement in the quality of the crop produced. It is also very probable that nitrogen could be used with profit on permanent meadow lands near the large markets in the eastern and southern states where the hay can be sold directly for a maximum price, with little or no expense for transportation.

On the other hand, the general farmer not only cannot afford to purchase commercial nitrogen, but there is absolutely no necessity whatever for him to do so. The air is about four-fifths nitrogen, and as the atmos-

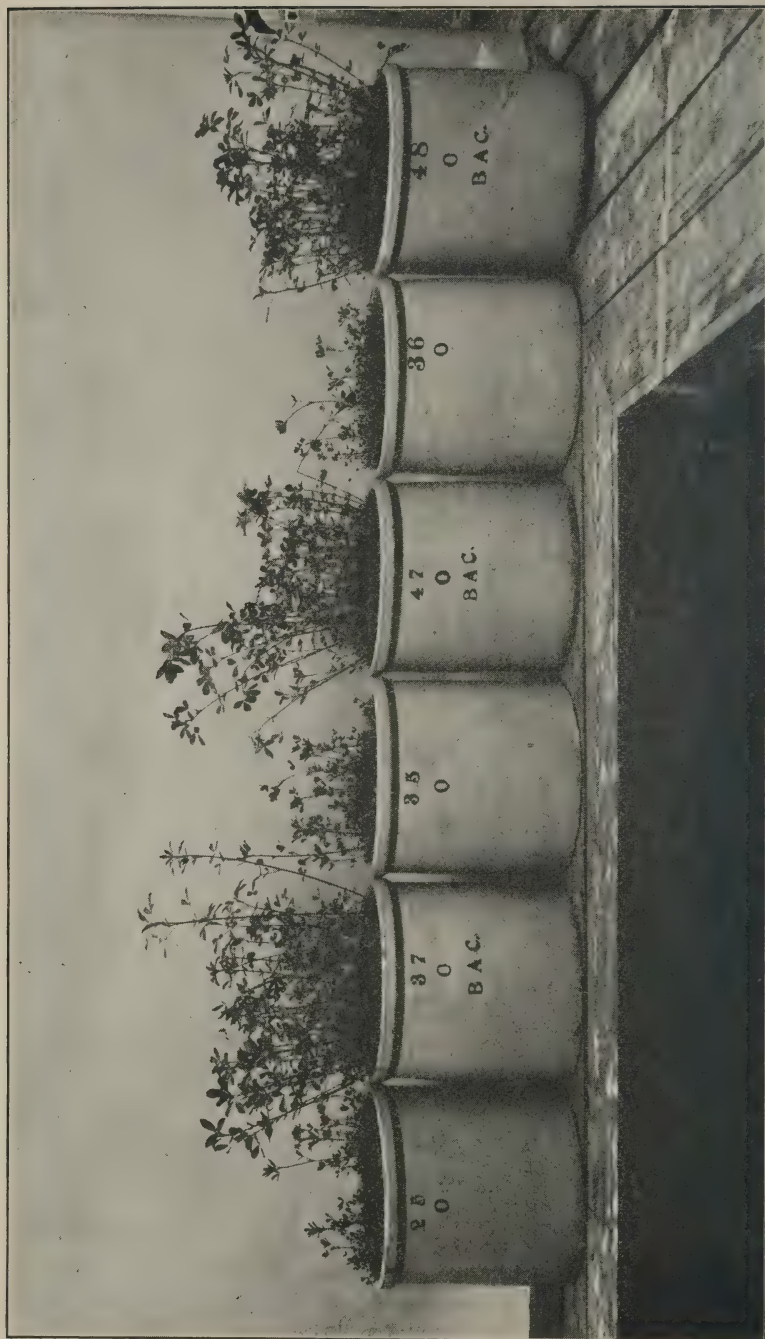


PLATE 6.—TRIPPLICATE TEST OF THE EFFECT OF ALFALFA BACTERIA IN GROWING ALFALFA IN ORDINARY FARM SOILS WITHOUT FERTILIZERS—JARS MARKED "BAC." CONTAIN ALFALFA BACTERIA.

pheric pressure amounts to about fifteen pounds to the square inch, there are actually nearly twelve pounds of nitrogen resting upon every square inch of the earth's surface, and although ordinary agricultural plants have no power to feed upon this free nitrogen of the air (being dependent upon the combined nitrogen in the soil for their supply), we now know that by means of the different species of nitrogen-gathering bacteria which inhabit or should inhabit the roots of different legumes, nitrogen can be obtained from this free and inexhaustible supply of the atmosphere for about 1 cent a pound. Thus, for example, we can sow red clover in the wheat, oats, or rye for less than \$1 an acre and grow a crop of clover containing more than 100 pounds of nitrogen an acre. We can also accomplish this result with a catch crop of cow peas, soy beans, or vetch, and probably with crimson clover or alfalfa after our soils become thoroughly infected with the proper bacteria. Exact investigations have shown that alfalfa properly infected with the alfalfa bacteria obtains practically all of its nitrogen from the air, even when grown on the black prairie soils of central Illinois.

The alfalfa grown in pots 37, 47, and 48, Plate 6, obtained about 90 percent of its total nitrogen content from the air. (All of these pots were filled with ordinary Illinois black prairie soil, which had been thoroughly mixed before the pots were filled. The only difference among the six pots is that alfalfa bacteria were added to the three pots marked "Bac.," thus enabling the alfalfa in those pots to obtain nitrogen from the air. Our Bulletin No. 76, "Alfalfa on Illinois Soil," will be sent upon request to any Illinois farmer or land owner who may be interested in alfalfa.) We have also found that the poorer the soil the greater is the proportion of nitrogen taken from the air, as compared with that taken from the soil.

In this connection it may be well to call attention to the fact that it is not necessary to apply any nitrogen to the soil in order to enable legumes to start growing. We have obtained a good stand and luxuriant growth of legumes in a soil which was absolutely free of nitrogen, simply by providing suitable conditions, including a sufficient supply of the mineral elements of plant food (as phosphorus and potassium), lime, if needed, and thorough inoculation with the proper species of nitrogen-gathering bacteria.

What then is the commercial value of nitrogen? Manifestly, what it costs to get it. In general farming it is probably safe to say 1 cent a pound—for nitrogen already delivered and spread over the ground.

The commercial value of phosphorus varies with the form in which it is purchased. Ground rock phosphate, containing at least 12 to 13 percent of the element phosphorus, can be bought in carload lots for \$7 to \$8 a ton delivered at almost any point in Illinois. This amounts to say \$7.50 for 250 pounds of phosphorus, or 3 cents a pound for the element. Fine ground steamed bone meal containing 12 to 13 percent of phosphorus

can be bought delivered at any railway station in the state for \$25 to \$30 a ton. In this form the phosphorus costs about 12 cents a pound. Aside from ground rock phosphate, the steamed bone meal is the cheapest form of phosphorus on the market. The bone meal is known to be a very satisfactory form of phosphorus to use and the results of our experiments with it prove that it acts readily as a source of phosphorus for wheat. It has not been treated with acid and is suitable for use on any soil in the State which needs phosphorus. As stated in Circular No. 68, pages 16 and 17, some experiments have been conducted (and are still in progress), which strongly indicate that, for equal amounts of money invested in ground rock phosphate and bone meal, the ground rock phosphate will give about as good immediate results when applied in connection with a liberal use of legumes or farm manure, and will be more lasting in its effect, than the bone meal. On the other hand, it would have practically no agricultural value if applied to a soil exceedingly deficient in organic matter unless accompanied by an application of farm manure or a liberal use of legumes.

The commercial value of the element potassium is about 6 cents a pound. The cheapest form of potassium is potassium chlorid, which contains about 42 percent of this element and costs about \$50 a ton. (See Circular No. 68 for more complete explanations regarding the elements of plant food, how and where they can be obtained, methods of application, etc.)

Returning to the discussion of the yield of wheat from the untreated plot on the Cutler Soil Experiment Field, it will be seen by reference to Table 1, page 4, of Circular No. 68, that six bushels of wheat and accompanying straw would remove from the soil about ten pounds of nitrogen, one and two-thirds pounds of phosphorus and seven pounds of potassium. Allowing 1 cent for nitrogen, 3 cents for phosphorus and 6 cents for potassium as the commercial value of these elements, the six-bushel crop of wheat would remove 10 cents worth of nitrogen, 5 cents worth of phosphorus and 42 cents worth of potassium from the soil, making a total of 57 cents from an acre. If we consider the commercial value of phosphorus as 12 cents a pound, as it is in bone meal, then we have removed 20 cents worth of phosphorus or 72 cents worth of the three elements. We shall certainly be within safe limits to place phosphorus at 12 cents a pound, as it can be obtained in bone meal for that price. (Bone meal is a form of phosphorus which has been used for many years and it is known to be reliable and to give good results, consequently we are safe in basing our computation upon the price of phosphorus in bone meal, although it is believed that when used under proper conditions phosphorus in the form of ground rock phosphate will prove to be more economical.)

Plot No. 1: No treatment. If we allow \$3.60 for the six bushels of wheat and then deduct \$2 for interest on the investment and 72 cents

for plant food removed from the soil, we have left 88 cents to pay for raising an acre of wheat.

Plot No. 2: Legume treatment. This plot yielded 9.2 bushels per acre, which at 60 cents would amount to \$5.52. The cost of seed and seeding for a catch crop of legumes is about \$1 an acre, varying of course with the kind of seed and method of seeding. The commercial value or cost of replacing the plant food removed by a wheat crop yielding 9.2 bushels amounts to \$1.10. Adding to this the cost of legume treatment and \$2 for interest on the investment makes \$4.10, leaving 1.42 cents to pay for raising an acre of wheat. (It may be stated that we have really allowed double pay for providing nitrogen, first by paying \$1 for the legume treatment, second by charging 1 cent a pound for the fifteen pounds of nitrogen removed in the crop.)

Plot No. 3: Manure treatment. This plot yielded 12.1 bushels per acre, which at 60 cents a bushel would amount to \$7.26. The value of the plant food removed by a wheat crop yielding 12.1 bushels amounts to \$1.45, counting 1 cent for nitrogen, 12 cents for phosphorus, and 6 cents for potassium, per pound.

It is exceedingly difficult to estimate the cost of the manure treatment. If the farmer has the manure on hand he may consider that the only cost is the hauling and spreading. Even if he hires the work done this should not amount to more than 30 cents a ton or \$4.80 for the sixteen tons which were applied. With \$2 for interest, \$1.45 for plant food removed, and \$4.80 for the manure treatment, we have a total of \$8.25 expense, or 99 cents more than the total value of the crop, which was \$7.26. In other words, if we consider the first year only, we have lost 99 cents an acre besides the entire expense of raising an acre of wheat. This would make a poor showing indeed for the manure treatment; but we have here another factor to consider, namely, that the value of the manure is not exhausted with the first crop. In fact, it is usually of greater benefit to the second crop than to the first and continues to benefit succeeding crops for several years. (Attention is called to the fact that this is also true with legume crops to some extent, and in some cases even when the entire crop is removed, only the stubble and roots being left with the soil.)

By reference to Table 2, page 12, of our Circular No. 68, it will be seen that a ton of average farm manure contains ten pounds of nitrogen, two pounds of phosphorus, and ten pounds of potassium; or sixteen tons of manure would contain 160 pounds of nitrogen, 32 pounds of phosphorus, and 160 pounds of potassium. The fact that the effect of applying manure lasts for many years is evidence that the elements of plant food which it contains are not in a readily available form. The phosphorus in manure should be as valuable as that in ground rock phosphate, and probably the potassium in manure should be valued on about

the same basis; that is, one-fourth as much as in a readily available form like potassium chlorid. With nitrogen at 1 cent, phosphorus at 3 cents, and potassium at $1\frac{1}{2}$ cents, manure would be worth 31 cents a ton, or \$4.96 for the sixteen tons. There may be some question whether $1\frac{1}{2}$ cents a pound for the potassium in manure is a fair estimate. We believe that it is. By referring to Table 4, it will be seen that although the manure applied to plot 7 contained 160 pounds of potassium, most of it was not available for use of the crop, because where we added commercial potassium (plot 9) in connection with the manure the yield was increased from 20.8 to 24 bushels per acre.

Manure treatment should be considered as adding to the value of the land. If the untreated land is worth \$40 an acre, it is worth \$44.80 after sixteen tons of farm manure have been applied to it. The added plant food becomes a part of the permanent investment, I say *permanent* because it is about as permanent as the value of the land itself. In some places in the eastern states, land which was once worth \$100 an acre or more is now worth \$35. Why? Chiefly because valuable plant food has been sold off. A twenty-bushel wheat crop removes 82 cents worth of plant food, counting nitrogen at 1 cent, phosphorus at 3 cents, and potassium at $1\frac{1}{2}$ cents a pound. In seventy-five years this would amount to over \$60 worth of plant food. This amount would practically cover the decrease in the value of the land. The farmers of southern Illinois are in a better position to appreciate these facts than those who are selling 60 bushels of corn a year off from the comparatively new and naturally rich black land in the north central part of the state.

Returning to the specific discussion of plot No. 3 (manure treatment), if we allow interest on \$44.80, we only add 24 cents to the annual expense, aside from paying for the larger amount of plant food removed. On this basis plot No. 3 should be credited with 12.1 bushels at 60 cents, amounting to \$7.26, and charged with \$2.24 for interest and \$1.45 for plant food removed. Deducting \$3.69 from the total receipts leaves \$3.57 to pay for raising an acre of wheat.

Plot No. 4: Legume, lime. This plot yielded 13.5 bushels of wheat worth \$8.10. The cost of an application of slacked lime or ground limestone (one to two tons per acre), will amount to from \$3 to \$6 an acre, but to be safe, even for strongly acid soils, let us say \$10 an acre. This is a direct investment and it must be added to the value of the land, making it \$50 an acre. In addition to this it may be necessary to apply half a ton of ground limestone every five or six years to keep the soil free from acidity or we may say that 25 cents worth of lime per acre is destroyed each year by cropping. In this connection it may be said that ground rock phosphate contains large amounts of lime and other basic materials (usually some lime carbonate) and it is not improbable that moderate annual applications of ground rock phosphate will be quite

sufficient to keep the soil free from acidity, after it has once been corrected by the initial application of lime.

With \$2.50 for interest, \$1 for legume treatment, and \$1.87 for plant food removed by the crop (including the lime destroyed), we have a total of \$5.37 to be deducted from \$8.10 leaving a balance of \$2.73 to pay for raising an acre of wheat.

Plot No. 5: Manure, lime. (The chief benefit of the lime on this plot will doubtless be for the growth of the legume in the regular rotation.) This plot yielded 13.3 bushels of wheat, worth \$7.98. After deducting \$2.74 for interest and \$1.85 for plant food removed, we have left \$3.39 to pay for raising an acre of wheat.

Plot No. 6: Legume, lime, phosphorus. This plot yielded 20.3 bushels of wheat in 1903, but we must also credit this plot with the increase of 3.7 bushels which this treatment (or the phosphorus alone) produced in 1902. This makes a total credit of twenty-four bushels, worth \$14.40. The seventy-eight pounds of phosphorus applied would cost \$9.36 at 12 cents a pound. This must be added to the value of the land, making the total value \$59.36. With \$2.97 for interest, \$1 for legume treatment, and \$3.13 for plant food removed, we have \$7.10 to be deducted from \$14.40, leaving a balance of \$7.30 to pay for raising an acre of wheat.

Plot No. 7: Manure, lime, phosphorus. This plot yielded 20.8 bushels of wheat. Adding the increase of 3.7 bushels produced by the phosphorus applied for the 1902 crop, we have 24.5 bushels worth \$14.70. Deducting \$3.21 for interest and \$3.19 for plant food removed, we have left \$8.30 to pay for raising an acre of wheat.

Plot No. 8: Legume, lime, phosphorus, potassium. This plot yielded 26.8 bushels in 1903. Adding the increase of 7.5 bushels produced by the phosphorus and potassium in 1902, we have 34.3 bushels of wheat, worth \$20.58. The 120 pounds of potassium applied to this plot at 6 cents a pound make \$7.20, which must be added to the value of the land, making the total value \$66.56 an acre. With \$3.33 for interest, \$1 for legume treatment, and \$4.37 for plant food removed, we have a total of \$8.70 to be deducted from \$20.58, leaving a balance of \$11.88 to pay for raising an acre of wheat.

Plot No. 9: Manure, lime, phosphorus, potassium. This plot yielded twenty-four bushels. Adding the increase of 7.5 bushels from the 1902 crop makes 31.5 bushels worth \$18.90. The cost of this land is now \$40 for the untreated land, \$4.80 for manure, \$10 for lime, \$9.36 for phosphorus, and \$7.20 for potassium, making the total cost \$71.36 an acre. With \$3.57 for interest and \$4.03 for plant food removed (including 25 cents for lime destroyed) amounting to \$7.60 we have left from the \$18.90 receipts a balance of \$11.30 to pay for raising an acre of wheat.

TABLE 7.—RESULTS OF SOIL TREATMENT: CUTLER EXPERIMENT FIELD.

Soil plot No.	Soil treatment applied to gray silt loam of the lower Illinoisan glaciation.	Total cost of land per acre.	Expense statement.			Wheat obtained.		Received for raising an acre of wheat.
			Interest on investment.	Cost of legume treatment.	Value of plant food removed.	Expense per acre.	Bushels per acre.	Value per acre.
201	None	\$40.00	\$2.00	....	\$0.72	\$2.72	6.0	\$0.88
202	Legume	40.00	2.00	\$1.00	1.10	4.10	9.2	1.42
203	Manure	44.80	2.24	....	1.45	3.69	12.1	3.57
204	Legume, lime	50.00	2.50	1.00	1.87	5.37	13.5	2.73
205	Manure, lime	54.80	2.74	....	1.85	4.59	13.3	3.39
206	Legume, lime, phosphorus	59.36	2.97	1.00	3.15	7.10	24.0	7.30
207	Manure, lime, phosphorus	64.16	3.21	....	3.19	6.40	24.5	8.30
208	Legume, lime, phosphorus, potassium	66.56	3.33	1.00	4.37	8.70	34.3	11.88
209	Manure, lime, phosphorus, potassium	71.36	3.57	....	4.03	7.60	31.5	11.30
210	Lime, phosphorus, potassium	66.56	3.33	....	3.68	7.01	28.6	10.15

Plot No. 10: Lime, phosphorus, potassium. This plot yielded 21.1 bushels, which with the 7.5 bushels increase from the previous year, makes 28.6 bushels, worth \$17.16. Deducting \$3.33 for interest and \$3.68 for plant food removed, leaves a balance of \$10.15 to pay for raising an acre of wheat.

Table 7 shows these data from the different plots in concise form for easy comparison.

Of course these computations might be somewhat modified for different conditions, depending upon distance of the farm from the railroad station, the price of wheat, the amount of lime required to correct the acidity of the soil, the amount of potassium found most profitable, etc., etc. It is believed that the estimates which have been made are on the safe side for the farmer. The expense of applying the manure, the lime, and the legume treatment has been included in the tabular statement, either in the investment (when the application lasts for many years) or in the annual expense (as with the legume treatment). The cost of the phosphorus and potassium is based upon well-recognized, trustworthy standard forms of those elements, allowing the full market price for them. No allowance has been made for the expense of applying those two elements, because there is practically no expense necessary. Even if both phosphorus and potassium are used, they can be applied at once by means of a fertilizer drill provided with fertilizer, grain, and grass-seed attachments, such as the Superior fertilizer disk drill. We have used this drill in this way and know that it can easily be done. Thus we can run bone meal through the force-feed grain box and run potassium chlorid through the regular fertilizer box, and at the same time we mix the fertilizers as they fall, probably more perfectly than any fertilizer manufacturer does or can do. Furthermore, we can make any brand of fertilizer we choose by simply varying the feed of the two boxes. Thus we can sow 200 pounds of bone meal and 100 pounds of potassium chlorid; or we can sow 300 pounds of bone meal and 50 pounds of potassium chlorid, or almost any other proportions we may desire.

If only one fertilizer is used, as bone meal, it can be run through the fertilizer box at the same time the seed is run through the grain box. By some people it is considered the best practice to drill the fertilizer one direction and then drill the grain crosswise. In this case both boxes could be used for fertilizers the first time over the ground. By using a disk drill the ground can be disked at the same time. There is no objection to sowing bone meal (raw, common, or steamed) or ground rock phosphate, or ground limestone through the fertilizer box at the same time as the seed is sowed, letting the fertilizer and grain fall together in the same drill row, but this should not be allowed with potassium salts or with acidulated bone meal, or any other acid phosphates because of the injurious effect of such fertilizers upon the germination of the seed. An

end-gate seeder can also be used for applying bone meal, ground rock phosphate, potassium salts, or light applications (500 to 1,000 pounds) of ground limestone. If potassium is used it can be applied broadcast very rapidly with an end-gate seeder, and then the phosphorus can (in bone meal or ground rock phosphate) be applied through the fertilizer box at the same time the seed is put in, with no danger of injuring the seed and with practically no extra expense. Any of these materials can also be applied by hand very rapidly, and, if care is taken, very uniformly. A man can stand in a wagon (with a boy to drive) and he can spread any of these materials over twenty acres in a day. Last spring one man in Whiteside County spread potassium sulfate at the rate of 100 pounds to the acre over twenty-two acres of swamp land in less than one day's time, and the results obtained in the crop show that it was applied very satisfactorily.

For general farming in Illinois, there is absolutely no need of a ready mixed fertilizer. It costs the manufacturer from \$4 to \$8 a ton for mixing bone meal with potassium chlorid (or at least the mixed goods cost the consumer that much more than the raw materials). The manufacturer is frequently obliged to grind up rock or stones or some other worthless waste material and mix it with the plant food material which he puts in, in order to be able to put the price per ton down so that foolish farmers will buy it. Of course, if the farmer says he will buy "fertilizer," but he "won't pay more than \$20 a ton for it," the dealer is bound to get him goods that he can sell for \$20, or even for \$15 a ton if necessary. Sometimes land plaster or gypsum (calcium sulfate) is used as the "filler," or "make weight." This material acts as a stimulant to the soil, causing it to give up some plant food and sometimes for a year or two to yield somewhat better crops, but it contains none of the valuable elements of plant food, and its action is simply more completely to exhaust the soil of its remaining stock of native fertility, finally to leave the land in even worse condition than before it was used. Acid phosphate such as acidulated bone meal, acidulated rock phosphate, and so-called superphosphates, all contain about 50 percent or more of gypsum, produced in the regular process of manufacture, besides the gypsum which is sometimes added as "make weight."

No general farmer in Illinois needs to purchase more than two elements of fertility. These are phosphorus and potassium. Bone meal will furnish the phosphorus and potassium chlorid the potassium, in the cheapest forms which are known to be available and without injurious effects on Illinois soils. Yet there are sold every year to general farmers in the United States more than a thousand different brands of fertilizers. Most of them contain more or less nitrogen (which costs the purchaser at least 15 cents a pound, but which he could get from the air for about 1 cent a pound); otherwise they have no value except

for the phosphorus and potassium which they may contain. Some fertilizer manufacturers evidently prefer to have the farmer know nothing about soil fertility and fertilizers, excepting that their "Big Ox Brand," or their "Money Maker" or "Corn Grower" is the only and all sufficient fertilizer for all soils if not even for all crops. Some soils are deficient in nitrogen and consequently need to grow legume crops; some soils need phosphorus; and some soils have an abundance of both nitrogen and phosphorus (more than the most productive black prairie soils in the state), and yet are exceedingly deficient in potassium (see Table 4, page 20 of Circular No. 68). On the other hand, some crops require many times as much of one element as some other crops. (See Table 1, page 4, of Circular No. 68.)

It is a pleasure to state that, as a rule, the fertilizer manufacturers and dealers in Illinois are working in harmony with the University of Illinois to encourage the farmers in this state to try to understand what their soils need to increase the yields of the crops they grow, and I think farmers who desire to try phosphorus on their land will have no difficulty in obtaining pure bone meal from such trustworthy firms as Nelson Morris & Company, Union Stock Yards, Chicago, Armour Fertilizer Works, Swift & Company, or from several other companies located at the Union Stock Yards. Several of these companies, including the Armour Fertilizer Works, also sell pure potassium salts, such as potassium chlorid (sometimes incorrectly called "muriate" of potash) and potassium sulfate.

As a rule, not more than one of these two elements, phosphorus and potassium, is needed on the soils of the state, although it may be that both elements can be purchased with profit for use on some southern Illinois soils.

The element phosphorus can be purchased for about 12 cents a pound in bone meal, or for about 3 cents a pound in ground rock phosphate. Good steamed bone meal and good ground rock phosphate each contain about twelve to thirteen pounds of phosphorus in 100 pounds of the material. The element potassium can be purchased for about 6 cents a pound in potassium chlorid. One ton of commercial potassium chlorid (containing about 80 percent of pure potassium chlorid and 20 percent of sodium chlorid, or common salt) contains about 840 pounds of the element potassium, which, at 6 cents a pound, makes it worth \$50.40. It can be bought from Chicago dealers for about \$50 a ton. Of course freight charges from Chicago must be added to the Chicago price.

The fertilizer law of Illinois requires that every bag of fertilizer which is sold in this state must bear a printed label stating the percentage of the different elements of fertility which it contains, and any farmer can tell from the printed guarantee just what a bag of bone meal contains. Thus, if the label guarantees the goods to contain $12\frac{1}{2}$ percent of phos-

phorus, this means twelve and a half pounds of the element phosphorus in 100 pounds of the bone meal, or 250 pounds of phosphorus in one ton of the bone meal. If the phosphorus is worth 12 cents a pound, such bone meal as this would be worth \$30 a ton. Good steamed bone meal contains from 12 to 13 percent of phosphorus and is usually sold at retail for about \$28 a ton at almost any place in Illinois.

In this connection, it may be said that the statements printed upon bags of fertilizers are commonly quite complicated. For example, the following statement may be given as the guaranteed analysis of a fertilizer:

Name, "**Soluble Ammoniated Bone and Potash.**"

ANALYSIS.

Available nitrogen	1.25 to 2.50
Available ammonia	1.50 to 2.75
Available phosphorus	4.00 to 5.50
Available phosphoric acid	9.00 to 12.00
Equal to bone phosphate	20.00 to 26.00
Total phosphorus	6.75 to 8.50
Total phosphoric acid	15.75 to 18.50
Equal to bone phosphate	34.25 to 42.50
Soluble potassium	1.50 to 3.25
Soluble potash	1.75 to 3.50
Equal to potassium sulfate	3.25 to 6.50

Now, what does this all mean? To understand this analysis, the farmer should first cut out everything except the minimum guarantee of the elements, nitrogen, phosphorus and potassium, as indicated by the bold-face type. To say that a fertilizer contains from 4.00 to 5.50 percent of phosphorus does not necessarily mean that it contains more than 4.00 percent, and 4.00 percent is really all that is guaranteed. Furthermore, it should be borne in mind that the law allows (and very properly so) a deficiency of 1 percent below the guarantee before it is considered positive evidence of fraud, consequently, the fertilizer may contain only 3 percent of phosphorus, under a guarantee of 4.00 to 5.50 percent, and still be within the limits of the law. It should be stated, however, that goods from trustworthy manufacturers are usually up to their minimum guarantee. Nevertheless it will be seen that a fertilizer might be sold with this long statement of the analysis as given above and complying strictly with the law, it might nevertheless contain only the following percentages (or pounds per hundred):

Available nitrogen	.25
Available phosphorus	3.00
Total phosphorus	5.75
Soluble potassium	.50

Now, it should be understood that the farmer does not need to purchase nitrogen, and consequently that item should not be considered as adding to the value of the fertilizer. Even if he did wish to buy nitrogen this amount, .25 percent, is less than is contained in a normal fertile soil. In other words, the ordinary black prairie soils of Illinois are worth as much a ton for a fertilizer as the nitrogen value of a ton of any com-

mercial fertilizer which contains only .25 percent of nitrogen and which may be lawfully guaranteed to contain 1.25 percent (some peaty soils found abundantly in Illinois contain about 3.50 percent of the element nitrogen). Many soils in the state also contain more than .50 percent of potassium, and a fertilizer should not be considered much more valuable because it contains ten pounds of potassium in a ton (either potassium chlorid or potassium sulfate contains 800 pounds of potassium in a ton (see Circular No. 68, pages 4 and 11).

In this connection attention is called to the fact that fertilizers are frequently labeled "Dissolved Bone," "All Soluble Bone," etc., which are not made from bone meal at all, but from acidulated rock phosphate. As rock phosphate contains a small amount of potassium, perhaps .5 percent, and as the sulfuric acid used in manufacturing acid phosphates usually contains a small amount of nitrogen, a plain acid phosphate could be made which would conform to the above long statement of analysis within the letter of the law, but the farmer should immediately reduce such a statement to

Available phosphorus	4.00 percent.
Total phosphorus	6.75 percent.

and the absolute guarantee is practically only

Available phosphorus	3.00 percent.
Total phosphorus	5.75 percent.

This means that one ton of this fertilizer contains sixty pounds of available phosphorus worth 12 cents a pound, or \$7.20, and fifty-five pounds of insoluble phosphorus worth not to exceed 3 cents a pound, or \$1.65. Thus this fertilizer would be worth \$8.85 a ton. Of course it ought not to be used on Illinois soils, because of the fact that it is an acid phosphate and, so far as we have yet learned from our soil investigations, the soils which need phosphorus are already too acid, and consequently we advise farmers against the use of acid phosphates. We also strongly recommend that they do not buy mixed fertilizers.

If phosphorus is needed (as it is on many soils in the state) buy fine ground bone meal (either raw bone, pure bone, or steamed bone, the last preferred) and apply it in moderate quantities, say 200 pounds an acre a year, or buy ground rock phosphate and apply at least 500 pounds an acre a year in connection with legumes or manure or both.

If potassium is needed, buy potassium chlorid or potassium sulfate and apply 50 to 100 pounds an acre a year. The first application on lands which are very deficient in potassium (as some of the swamp lands) should be about 200 pounds for the most profitable returns. By reference to page 4 of Circular No. 68, it will be seen that the grain and stover for 100 bushels of corn require seventy-one pounds of potassium. It would take about 175 pounds of potassium chlorid or potassium sulfate to furnish seventy-one pounds of the element potassium. Of course the roots of corn also require potassium.

If any one prefers to pay \$16 to \$17 a ton for kainit, containing 10 percent of potassium, than to pay \$50 to \$55 a ton for potassium chlorid, containing 42 percent of the element potassium, of course he has the privilege of paying about 8 cents a pound for potassium and of handling four tons of material instead of one. Incidentally he pays the freight on three tons extra of common salt and other worthless material contained in the kainit, which is shipped all the way from the potash mines of Germany.

We especially recommend fine ground steamed bone meal for phosphorus and potassium chlorid for potassium.

SUMMARY OF BULLETIN No. 88.

The results thus far obtained from the soil investigations reported in this bulletin certainly justify drawing some very definite conclusions. The amounts which are mentioned as the price received for raising an acre of wheat is for seed, labor, use of tools, cost of threshing and marketing. The interest on the investment (including the original land value and the added stock of fertility of somewhat permanent character), the total cost of annual soil treatment, and full payment for all fertility removed in the total crops (including nitrogen, which is really also covered by the cost of legume treatment allowed in the expense of annual treatment) have all been provided for outside of these net amounts which remain to pay for raising an acre of wheat. Furthermore the value of the straw has not been considered, although the fertility which it contains has been provided for. The price of wheat has been counted at 60 cents a bushel, which is surely conservative. It is believed that the results reported are thoroughly trustworthy.

First. Legume treatment for this soil is profitable as compared with no treatment. Legume treatment alone increased the amount received for raising an acre of wheat from 88 cents to \$1.42, and when the legume treatment was omitted from plot 8 (see plot 10), the amount received for raising an acre of wheat decreased from \$11.88 to \$10.15, making a reduction of \$1.73 in the profits, even after allowing \$1 for the expense of the legume treatment, and not taking into account the fact that the effect of the legume treatment will last more than one season.

Second. Manure made on the farm can be applied to the soil with marked profit. (The untreated plot paid only 88 cents for raising an acre of wheat, while the manured plot paid \$3.57.)

Third. Moderate applications of ground limestone to acid soils give evidence of marked improvement in the growth of legumes, but more data are necessary to determine fully the extent of this improvement.

Fourth. The application of phosphorus is very profitable soil treatment. (It should be applied only in connection with manure or legume treatment, unless the soil is already well supplied with nitrogen and

organic matter.) Applied with legumes and lime, the phosphorus increased the amount received for raising an acre of wheat from \$2.73 to \$7.30. When applied with manure the increase was from \$3.39 to \$8.30.

Fifth. Potassium has also been applied with profit especially when used in connection with legumes and phosphorus, the amount received for raising an acre of wheat having been increased from \$7.30 (legume, lime, phosphorus) to \$11.88 (legume, lime, phosphorus, potassium) by the addition of potassium, making an increased profit of \$4.58. (Phosphorus made \$4.57.) It should be understood that the use of potassium without phosphorus would undoubtedly result in loss on nearly all Illinois soils (swamp soils excepted).

In this connection attention is called to the effect of tile drainage in supplying potassium. As a matter of fact, practically all of the soils of the state (swamp and sand soils excepted) contain large supplies of potassium in the subsoils, say between twenty and forty inches below the surface. Tile drains laid at a depth of forty inches permit the excessive soil water to pass off quickly thus causing the soil to become more porous and allowing the air to enter to encourage nitrification and the liberation of plant food from the subsoil. The plant roots are encouraged to grow deep into the soil and thus obtain potassium which they could not obtain if the subsoil was waterlogged more or less of the time during the season.

The results already obtained in support of such a theory are very meager and somewhat conflicting, and more data are needed and are being obtained as rapidly as possible. However, in view of the facts, first that applications of potassium have markedly increased crop yields on this type of soil, and second, that the subsoil is actually rich in potassium, it seems worth while to call attention, tentatively at least, to the data given in the preceding tables indicating that tile-drainage may perhaps be just as effective and more economical as a means of supplying potassium to the growing crops, altogether aside from the other marked benefits which tile-drainage produces.

By referring to Table 2 it will be seen that results are reported from our tile-drained soil experiment field at Odin. The tile-drainage increased the yield of oats in 1902 from 16.7 to 19.2 bushels, where legume treatment, lime, and phosphorus had been applied, and in 1903 the tiled plot with this treatment yielded 13.4 bushels of wheat, while the corresponding untiled plot yielded only 5.8 bushels. It will also be noticed that the application of potassium increased the yield of wheat from 5.8 to 14 bushels on untiled land, while on the tiled land the increase due to the application of potassium was only from 13.4 to 15.2 bushels. Potassium benefited the oats on the untiled land but it appears even to have reduced the yield on the tiled land. These results indicate quite strongly that tile-drainage at Odin may enable the crops to get about



PLATE 7.—WHEAT CROP WITH NO TREATMENT: ORDINARY FIELD ON GRAY SILT IN ST. CLAIR COUNTY: ADJOINING FIELD SHOWN IN PLATE 8.

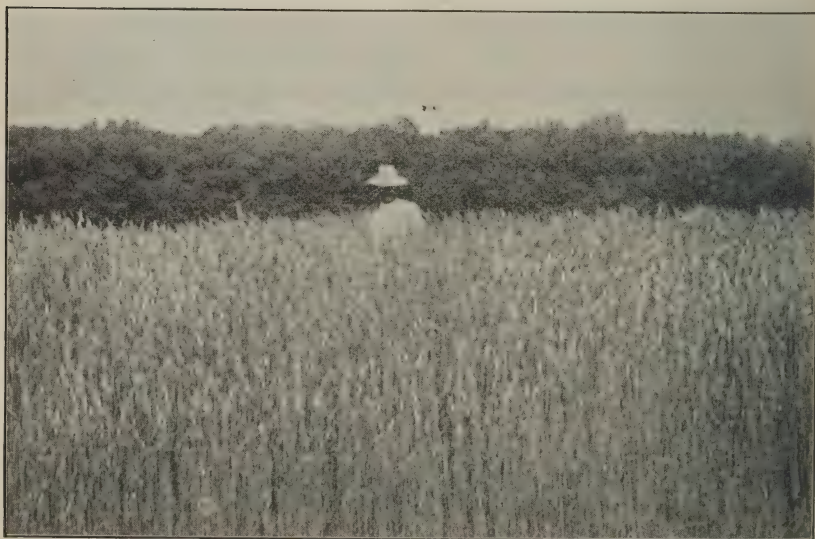


PLATE 8.—WHEAT CROP AFTER 40 LOADS WHEAT STRAW HAD BEEN LEACHED AND BURNED OFF: ADJOINING FIELD SHOWN IN PLATE 7.

as much potassium as they need. Of course more data are needed before final conclusions can be safely drawn.

In conclusion it should be stated that the season of 1903 was one of the worst for the wheat crop which has been known in southern Illinois for many years. It seems fair to expect more marked results and larger yields from our soil experiment fields in a normal season.

Special attention is called to the very evident fact that the poor season is not altogether to blame for the poor crop of wheat. We can realize this better when we remember that in the same field of wheat at Cutler one plot produced 6 bushels an acre and another 26.8 bushels; at Odin one plot produced 0.5 of a bushel an acre and another plot 15.2 bushels. Furthermore, it was possible to find some good patches of wheat almost everywhere throughout the wheat growing area of southern Illinois. For example, plate 7 shows the wheat crop growing in an ordinary field on the farm of Philip Postel located on the gray silt soil in St. Clair County, while plate 8 shows the wheat crop growing on "strawed potato" land immediately adjoining this field. The two crops as indicated in the photographs were growing within twelve feet of each other. The season was the same for each and the soil was originally exactly the same type and formerly of the same productive capacity.

Why is this difference? In answer, let me call attention to the facts that this excellent plot had grown potatoes in 1901, that these potatoes had been covered with some forty loads of wheat straw to the acre; that this straw had lain on the ground for a year, and what had not rotted or leached out during that time had been burned and the ashes containing the lime, phosphorus and potassium, not already leached out, had thus been added to the soil in readily available form.

By referring to Table 1, page 4, Circular No. 68, it will be seen that forty tons of wheat straw would thus supply to the soil eighty pounds of phosphorus and 680 pounds of potassium. That is two pounds more phosphorus and 560 pounds more potassium than we have applied to our soil experiment fields during two years' time, besides the straw must have furnished a considerable amount of nitrogen (leached into the soil before it was burned). This object lesson, picked up in passing the field, serves to confirm strongly the results obtained on the experiment fields and emphasizes the tremendous importance of plant food in crop production.

Note.—This bulletin is hurried to publication with the thought that it contains information of very great value to those southern Illinois farmers who will be sowing wheat within a few weeks. It is earnestly suggested that they begin at least in a small way to build up a piece of land and thus obtain some definite knowledge from their own farms. At least try 200 pounds of bone meal on half an acre either in connection with farm manure or where legumes have been grown, and observe the results for two or three years.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

BULLETIN NO. 90.

FATTENING STEERS OF THE VARIOUS MARKET GRADES.

By HERBERT W. MUMFORD



URBANA, DECEMBER, 1903.

SUMMARY OF BULLETIN No. 90.

OBJECT.—To determine the relative rapidity, extent, nature, and cost of gains with the six grades of feeding cattle, viz., fancy selected, choice, good, medium, common, and inferior. Page 157

PLAN.—Sixteen steers of each grade were fed alike from November 29, 1902, to May 27, 1903, a period of 179 days. Four pigs followed each of the six lots of steers. The feeds used were cracked corn, corn and cob meal, cotton seed meal, old process linseed oil meal, clover hay, alfalfa, timothy hay, and corn stover. Page 158

RAPIDITY OF GAINS.—Average daily gain per steer in pounds: Fancy, 2.57; choice, 2.54; good, 2.34; medium, 2.13; common, 2.21; inferior, 1.96. Total gain in pork in pounds for each lot: Fancy, 419; choice, 500; good, 475; medium, 520; common, 420; inferior, 480. Page 168

ECONOMY OF GAINS.—Average digestible dry matter in pounds required for producing a pound of gain in beef: Fancy, 9.95; choice, 12.09; good, 12.08; medium, 13.05; common, 12.00; inferior, 12.93. Number of pounds gain per bushel of corn consumed: Fancy, 9.74; choice, 7.97; good, 7.99; medium, 7.45; common, 8.13; inferior, 7.61. Page 170

COST OF GAINS PER POUND, AVERAGE.—Fancy, \$0.067; choice, \$0.082; good, \$0.082; medium, \$0.088; common, \$0.081; inferior, \$0.087. Page 170

NATURE OF GAINS.—As a result of feeding the 16 *fancy* feeders (lot 1) until finished there was only one steer that would not grade as prime. This steer lacked slightly in quality, but principally in condition, and graded as choice. After slaughtering, the beef experts in Armour & Company's city beef department graded all the carcasses as No. 1. Page 180

Of the 16 *choice* feeders (lot 2) fourteen finished as prime, one as choice, and one as good. All the carcasses graded as No. 1 beef.

Of the 16 *good* feeders (lot 3) three finished as prime, five as choice, and eight as good. All the carcasses graded as No. 1.

Of the 16 *medium* feeders (lot 4) one finished as choice, four as good, eight as medium, and three as common. Four of the carcasses in this lot graded as No. 1 light and the remainder as No. 2 tops.

Of the 16 *common* feeders (lot 5) five finished the test as good, six as medium, and five as common beefs. The grading of the beef was the same as that in lot 4, namely, four carcasses graded as No. 1 light, and twelve as No. 2 tops.

Of the 16 *inferior* feeders (lot 6) four finished as good, six as medium, and six as common. Six carcasses graded as No. 1 light, nine as No. 2 tops, and one as No. 3 beef.

PERCENTAGES OF DRESSED BEEF.—Average percentage carcass to live weight: Fancy, 61.62; choice, 61.52; good, 60.74; medium, 59.70; common, 59.88; inferior, 59.36. Page 178

PROFIT AND LOSS.—Market value as feeders November 29, 1902: Fancy, \$4.75; choice, \$4.55; good, \$4.20; medium, \$3.85; common, \$3.60; inferior, \$3.35 per hundred weight. Page 185

Market Value of Finished Cattle on Basis of Steady Market from November 29, 1902, to May 28, 1903.—Fancy, \$7.00; choice, \$6.90; good, \$6.50; medium, \$5.80; common, \$5.50; inferior, \$5.40. Page 190

Profit per Steer on Basis of Steady or Stationary Market.—Fancy, \$18.15; choice, \$15.67; good, \$11.56; medium, \$4.41; common, \$4.09; inferior, \$5.48. Page 191

Actual Selling Prices per cwt. when Marketed May 28, 1903, "Falling Market."—Fancy, \$5.40; choice, \$5.40; good, \$5.15; medium, \$4.90; common, \$4.80; inferior, \$4.80. Page 190

Loss per Steer on Basis of Actual or Falling Market.—Fancy, \$3.80; choice, \$7.44; good, \$7.36; medium, \$7.95; common, \$5.26; inferior, \$2.37. Page 191

DECLINE IN MARKET FROM BEGINNING TO CLOSE OF EXPERIMENT.—Fancy, \$1.60; choice, \$1.50; good, \$1.35; medium, \$0.90; common, \$0.70; inferior, \$0.60 per hundred weight. Page 194

Conclusions

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FATTENING STEERS OF THE VARIOUS MARKET GRADES.

By HERBERT W. MUMFORD, CHIEF IN ANIMAL HUSBANDRY.

INTRODUCTION.

In Bulletin No. 78 issued by this Station about a year ago, the writer illustrated and described the various market classes and grades of cattle as seen at our leading live stock markets. The two market classes receiving the greatest share of attention were beef cattle of the prime, choice, good, medium, and common rough grades; and feeders of the fancy selected, choice, good, medium, common, and inferior grades. Each grade of the fat cattle class was considered in all its relations to other grades of the same class, while each grade of feeders was described by comparing it with a standard grade of feeding cattle whose points of excellence were most uniform and characteristic. Thus it will be seen on the one hand that no attempt was made to indicate from what grades of feeders, prime, choice, good, or other grades of steers are developed or on the other how inferior, common, medium, good, choice, and fancy selected feeding cattle may be expected to feed out or finish in the feed lot. In a general way, men who make a business of buying and finishing feeders, handle largely one grade of cattle. They determine approximately their grade when sold by knowing how close to the top of the market they sell.

It is believed that all who finish cattle, either of their own breeding or those purchased as feeders in the market, will become more intelligent producers if they become more familiar with the possibilities of the various grades of feeding cattle. There is much of pecuniary value to the cattle feeder in knowing the correlation between the various grades of feeding cattle and the several grades of fat cattle.

Never did the results of an experiment in cattle feeding require more careful study and more serious thought than those to be presented in this bulletin. The reader is cautioned not to read parts of the bulletin and draw hasty conclusions, but to read and re-read all of it carefully and thoughtfully. An effort has been made to present the facts in such a manner as to avoid the possibility of the forming of misleading conclusions.

OBJECT OF THE EXPERIMENT.

The object of this experiment was to secure data for the accurate comparison of the six standard grades of feeding steers with respect to the following points:

1. The extent or quantity of gains.
2. The rapidity of gains.
3. The economy of gains as measured by feed consumed.

4. The nature of the gain as indicated by the different grades during the feeding period and as measured by their re-grading as beef or fat cattle at the end of the experiment, the percentages of dressed beef and the percentages of fat.

5. The comparative quality of the beef as expressed by the grading of the carcasses after slaughter.

6. The relative profit to the feeder after considering all elements of outgo and income,—that is, the initial cost of the various grades of feeders, their relative extent and quality of gain, the cost of feed, and the comparative selling price of the various grades as marketed,—first under normal conditions, that is, a steady market; second, under abnormal conditions, that is, a falling market.

In the interest of brevity these various points will be alluded to throughout the text as the “extent,” “rapidity,” “nature,” “economy,” and “cost” of gain, and the “profit” or the “loss” in feeding.

TABLE 1.—GRADES OF FEEDING CATTLE, BEEF OR FAT CATTLE, AND CARCASSES ON CHICAGO MARKET.

Feeding Cattle	Beef or Fat Cattle	Carcasses
Fancy	Prime	No. 1
Choice	Choice	No. 1 Light
Good	Good	No. 2 Tops
Medium	Medium	No. 2
Common	Common Rough	No. 3
Inferior		Canning Stock

The practical feeder very much desires to know the relative economy of production with these six different grades of feeders, and also the grade of finished cattle that may confidently be expected from each in order that he may calculate which will be most profitable after considering the greater initial cost and the relatively higher selling price of the better grades. It was to answer these questions that this experiment was undertaken.

PLAN OF THE EXPERIMENT.

The animals used were sixteen steers of each of the various grades of feeding cattle which were placed in feed lots and fed under uniform conditions; therefore this experiment involved the feeding of six car-loads of cattle. The fancy selected, the choice, the good, the medium, the common, and the inferior grades, as described in Bulletin No. 78 of this Station were each represented.

Experiments have been conducted with a few animals which have thrown some light on this subject, but never before have enough animals been used to eliminate individuality and thus make it safe to accept the conclusions reached without a certain amount of reserve.

The choice, good, medium, common, and inferior feeders used in this

experiment were purchased in the Union Stock Yards, Chicago, the fancy selected in Missouri. These were all strictly grass cattle as none had received grain while on grass. They were purchased in October, and shipped to the University farm where they were all turned together on pasture, remaining there without grain for about a month. This placed all the cattle to be used in the experiment under uniform conditions for a month and furnished us an opportunity to become more familiar with the individuality of the steers. They were taken from the pastures and confined in the feed lots about the middle of November, when they were gradually accustomed to a light ration of broken corn together with all the hay they would eat. During the last week in November the various grades were selected without attempting to place them strictly in the grades for which they were originally bought. When the steers were purchased, sixteen or more of each grade were selected. A few of the steers changed sufficiently within the month intervening between purchasing and placing in the feed lot to change slightly their grade. In the main, however, they were ultimately assigned to those grades which they were bought to represent. A systematic effort was made to secure native cattle in all the grades for this test. It was found, however, that the offerings at the Yards, while large, were still not sufficient to fill accurately the various grades without taking an occasional range steer. The few range steers that were selected were practically as useful for the object of the test as were the natives, since they were quiet and had apparently been previously accustomed to grain feeding during the preceding winter.

At the beginning of the experiment the cattle were examined by a committee of experts from the Chicago Stock Yards, consisting of Mr. John T. Alexander, of Alexander, Ward and Conover; Mr. George W. Shannon, of Shannon Brothers, and Mr. James Brown, expert cattle buyer for Armour & Co., whose judgment was asked with reference to the grading and the market value of each grade. The same committee visited the Experiment Station at intervals of one month for the purpose of determining the improvement of each grade in value per hundred pounds. The author desires to acknowledge his indebtedness to these gentlemen for their faithful and efficient services. Their expert judgment has been of the greatest value and importance to this experiment.

The market at the beginning of the experiment was fixed upon as the basis for all values assigned to the cattle. This was done in order to free the valuations from fluctuations in the market, thus making it possible to secure data on basis of a steady market. This committee continued their work up to and including the time of marketing. As the cattle were weighed every two weeks and as a careful record was kept of the rations fed, it is possible to determine at what time the various loads could have been marketed to best advantage.

It is advisable to give a brief description of the cattle in each grade at the beginning of the experiment. For convenience the various grades were given lot numbers as follows:

- Lot 1. Fancy selected feeders.
- Lot 2. Choice feeders.
- Lot 3. Good feeders.
- Lot 4. Medium feeders.
- Lot 5. Common feeders.
- Lot 6. Inferior feeders.

LOT 1. FANCY SELECTED.

It seemed impossible to find a car-load of fancy selected feeders on the Chicago market during October, 1902, hence it was necessary to look elsewhere for them. They were finally located on the farm of Wallace Estill of Missouri. It was difficult to secure sixteen cattle which would in every way meet the requirements of this grade. The feeding qualities of the cattle selected to represent this grade fully sustained judgment at the time they were purchased. They contained nearly one hundred percent of the blood of the improved beef breeds. The dams were high grade Shorthorn cows and the sire a registered Hereford. With one exception they bore the markings of the Hereford; this steer resembled his Shorthorn parentage as to markings and more so as to his conformation than did the other steers in this lot.

While there was a slight lack of uniformity in size in this load of steers, they possessed the quality and conformation that accompany the typical beef-bred steer. It is true that they were the youngest steers, as a lot, in the test, being about two years old at the time of marketing. It is also true that age, as well as quality, conformation, and condition, is characteristic of the various grades of feeding cattle. Usually when the better grades of feeding cattle are selected for feeding they are comparatively young. To make this point more clear it may be said that it would be impossible to secure a two-year-old inferior feeder, as inferior steers of this age would possess neither the weight nor the flesh demanded in the feeder class. In Bulletin No. 78 feeders were described as follows: "As a rule, we may classify as feeders, steers weighing 900 pounds or more that are eighteen months old or older, and that are fleshy enough so as not to render an extended period of low feeding necessary." Manifestly the slower maturing, lower grades will always be the older animals when feeding weights are attained.

The individual steers comprising this fancy grade possessed outstanding quality. They were the kind from which car-load show cattle are produced. Those who have attempted to collect such a group of cattle know how very scarce they are. Such feeding cattle are very seldom seen in any of our feeding-cattle markets, for when such a bunch is known to

be for sale it is usually eagerly sought, hence it is unnecessary to ship them to the market to find a buyer. While these steers had not received grain on grass, they were what would be termed "fleshy" feeders. See Plate 1.

LOT 2. CHOICE FEEDERS.

The steers in this group were unquestionably choice. They possessed large frames and perhaps averaged six months older than the fancy selected lot, though still younger than lots 4, 5, and 6. Owing to their more advanced age and the appearance of being more growthy, this load of steers was frequently selected by experienced feeders as the best calculated to produce the largest and most rapid gains of any in the test. They were the heaviest cattle entering the test and perhaps, everything considered, were carrying slightly more flesh than the others, although lots 1 and 2 were similar in this regard. These were purchased in the Union Stock Yards, Chicago, and were the best that had been seen on the market for a considerable time. They were high-grade Short-horns, uniform as to size, color, and conformation. Fed to a finish, steers of such quality ought to produce prime steers of sufficient merit to sell at the top on any ordinary market. See Plate 3.

LOT 3. GOOD FEEDERS.

The quality and finish so manifest in the choice and fancy-selected lots were not so much in evidence in this group, although it was easy to see that beef blood still predominated. While these cattle possessed a strong infusion of beef blood, they did not meet the requirements of the ideal feeder in type or conformation. They were inclined to be up-standing, while some of the steers were rather plain in their rumps. They lacked that attractive uniformity that characterized lots 1 and 2. As to condition they were hardly as fleshy as the grades already described. It should not be gathered from what has been said that these were an undesirable lot of feeding cattle, for they were not. In fact, cattle of their quality are not at all plenty in the markets of our country, and can only be produced by the use of bulls of some of the beef breeds. See Plate 5.

LOT 4. MEDIUM FEEDERS.

Undoubtedly the most noticeable characteristic of this group was its lack of uniformity in color. This suggests their probable mixed breeding. The lack of uniformity is not by any means the main difference between this and the better grades. A closer study reveals a coarseness and angularity not at all characteristic of those of better quality. There is a plain, old style appearance about them that is very evident. The cattle appeared to be close to three years old. Experienced feeders would select now and again a steer from this lot that would be expected to make large gains, and occasionally one that would finish quite smooth,

but the majority would always remain rather coarse, rough, and paunchy. It should be said that this lot did not contain a steer that failed to show evidence of improved beef blood, although the predominating blood seemed to be native or unimproved, with occasionally a dash of the blood of some one of the dairy breeds. See Plate 7.

LOT 5. COMMON FEEDERS.

This group showed but a very small percentage of beef blood. Native and unimproved blood predominated. There was no uniformity in color and every steer showed a lack of both quality and conformation. The steers were rather coarse boned and large headed, and were plain throughout. They did not all have similar faults, but all were noticeably deficient in some particular. They were the kind that result from the somewhat common practice of indiscriminate breeding and the too common practice of breeding from inferior grade bulls. See Plate 9.

LOT 6. INFERIOR FEEDERS.

There are so many standards by which feeding cattle might be designated as inferior that it is well to be explicit in specifying the standard employed in the selection of the cattle comprising this group. It was not that they should be steers carrying a high percentage of dairy blood, although two or three steers in this group were undoubtedly strongly dairy bred. Nor was it that they should be beef-bred steers of faulty conformation and lacking in constitution. An effort was made to select cattle inferior in quality and conformation from the standpoint of beef breeding, that is, those possessing very little, if any, of the blood of any of the improved beef breeds. This was a more difficult task than would seem to those who have not attempted it. The majority of this group were selected from a consignment of Virginia grass cattle shipped to the Chicago market. They showed no evidences of beef blood and every evidence of being scrubs. As such they were plain cold-blooded creatures, not at all pleasing to look upon. See Plate 11.

In general, the basis of selection in all these lots was quality, or beef breeding. In each instance where the grade called for well-bred beef steers they were selected not only with regard to their breeding, but care was taken that they should possess the qualifications which should accompany well-bred steers. In no case were steers selected to fill any of the grades that showed evidence of being poor and unprofitable gainers, and all were required to show equal evidence of health and thrift.

By referring to Table 3 it will be seen that the initial weights of lots 1, 5, and 6 were nearly the same, although lot 1 was the lightest of the three. Lot 2 was considerably the heaviest, while lots 3 and 4 were very similar in weight. These differences in weight were, with the

exception of lot 2, characteristic of the different grades used in the test.

The fact that the steers in lot 2 were so much heavier than those in the other lots should not be passed without comment. It has been shown why it was impracticable to secure steers of uniform age to represent the different market grades of feeding cattle. This was done, however, as far as practicable. By referring to the table it will be seen that there was but little variation in the average weight of the steers in the various lots, except that those in lot 2 were considerably heavier than those of any other lot. In order that justice should be done to all grades, it seemed reasonable to secure more age in the choice than in the fancy lot. Differences in the ages of the different grades were inevitable, but by securing an intermediate age in lot 2 which was one of the better grades, the factor of age as affecting cost of gains was largely eliminated. In securing more age and the quality which characterizes choice feeders it seemed necessary, to meet the requirements of this test, to get steers of rather heavy weight. It was not possible to secure cattle of uniform weight to represent the various grades without sacrificing other and apparently more important factors. It should also be noted that the differences in weight at the end of the experiment are much less marked than they were at the beginning.

In selecting steers for feeding with a definite idea as to when they are to be ready for the market, the cattle feeder must needs give careful attention to age, condition, and weight. In this instance feeders were wanted that could be finished with thirty to sixty days light and preliminary feeding, and one hundred to one hundred and twenty days full feeding. This being true, strictly grass cattle were selected.

SHELTER, FEED LOTS, AND WATER SUPPLY.

The shelter provided for the various grades of steers used in this experiment consisted of a low shed open to the south, very similar to the open sheds in common use for cattle feeding in the corn belt. It could hardly be said that the feed lots were like those commonly seen in Illinois, as they were all paved with brick. It is impossible to get two feed lots in which conditions would be precisely the same without some provision for keeping the cattle out of the mud. As the feed lots were small, 36x48 feet, with a 12-foot shed running along the north side, making the total size 36x60 feet, paving with brick seemed the most practicable system. The lots were not paved under the sheds, where the ground was protected from all surface water. The sheds were kept well bedded, but no attempt was made to bed the pavement. The lots were frequently cleaned, and in wet weather the consistency of the manure on the pavement was such that it could have been handled more

advantageously had litter of some sort been freely mingled with it. The price of bedding at the time prohibited its use for this purpose. During the day the steers had access to fresh pure water stored in galvanized steel tanks into which it was drawn from the University plant. Late in the evening of each day during the coldest weather the water was all drawn from the tanks by means of a convenient device in the bottom of each and carried away in a tile provided for that purpose.

METHOD OF FEEDING STEERS.

It should be borne in mind that, notwithstanding what may be subsequently said concerning the method of feeding and the feeds used in connection with this test, the experiment was primarily to test the feeding quality of the various grades of feeding cattle, while the feeds used and the manner of feeding the same were incidental rather than material and were the same for all lots. It seemed desirable to eliminate the pork-producing factor in this experiment as far as practicable; hence, the grinding of the grain seemed necessary. Corn and cob meal has given such universal satisfaction for cattle feeding that the use of the corn in this form promised good results. In seeking a nitrogenous roughage to supplement corn it was found that the quality of clover hay was universally bad and that it was impossible to secure good clover hay in sufficient quantities to warrant its use throughout the experiment. While clover and timothy hay were used in considerable quantities during the earlier part of the test, as soon as alfalfa could be secured it was used as roughage. Many well known cattle feeders have expressed the opinion from time to time that the chaffing or cutting of roughage and mingling it with the grain would prove the best method for economizing food. Except in a very few instances this method of feeding has never been used in an extensive way. The results of this experiment indicate that it is by no means an impracticable method of feeding. The clover and timothy hay, and later the alfalfa, were run through an ordinary ensilage machine which cut the hay into bits about two inches in length. This cut or chopped hay was mixed with the grain in certain definite proportions, as will be shown subsequently. During the early part of the experiment, cotton seed meal, and during the latter part, oil meal, were fed to supplement the corn, and these concentrates were an ingredient of the mixed feed which was fed the steers twice a day at six to seven in the morning and at four to five o'clock in the afternoon. Great care was taken to see that each lot was fed at the same hours each day.

The adoption of this system of feeding made it possible to keep very accurate records of all feed, both roughage and concentrates and to insure that the proportion of roughage to concentrates was always the same with all the lots.

The experiment began November 29, 1902, and for several weeks the ear corn was simply run through an ensilage machine, which cracked the corn and cobs. The grinding of the corn, cob and all, began about the middle of February. Toward the last of the feeding of the cracked corn and cobs the steers left a large part of the cobs.

The advantage of this system of feeding shows the possibility of converting a large proportion of the feed consumed into beef, profit not being so largely dependent upon the hog as a factor in beef production. There were very few cases of scours during the feeding period, and only two out of the 96 head were off feed during the entire time. These facts will at once commend this system to experienced feeders. It was not necessary to take out a single steer originally selected for the experiment, and the cattle were peculiarly free from sickness of any kind.

The cotton seed and linseed meal were both of good quality; the former was the "Dixie Brand," the latter "Old Process," pea size. The clover hay used was of poor quality, the timothy hay, medium, the alfalfa while not strictly choice, was good, and the stover was poor.

The cattle having been fed on broken corn for about three weeks prior to the beginning of the experiment and for a few days after, did not at first take kindly to the change from broken to cracked corn. In less than a week, however, they ate the cracked corn greedily. The grain and hay were fed separately for three weeks, after which time the hay was cut and mixed with the grain. They ate the mixed feed well from the start. The feeding of cotton seed meal was begun the fifth week of the experiment. The cattle did not eat it well at the start. In less than two weeks, however, they ate it greedily. For the first six weeks the amounts of corn and hay fed were about equal. At the beginning of the seventh week the proportionate weight of hay to corn was as one to two. Corn stover was fed to each lot one or two days a week during January and February in order to furnish variety and add the extra roughage which the steers seemed to relish. The appetite was kept keen by increasing the feed slowly and gradually. No indications of leaving feed were seen until about the end of the eighth week, when there was some tendency to leave some of the roughage part of the ration. This was taken as an indication that the amount of roughage to the grain fed was too great. Consequently the proportion was reduced to three-quarters corn to one-quarter hay. February 8, one-half the roughage fed was clover hay and the other half alfalfa. From February 11 to the end of the experiment practically all of the roughage fed was alfalfa. It proved a most excellent roughage. The droppings of the steers soon began to show that their bowels were in much better condition than when clover hay of poor quality was fed. By February 18 the steers were getting all the feed they would take. From this time on an effort was made to feed them all they would eat, care being taken not to force

them off feed. Not a steer of the whole 96 head scoured until March 23, when one in lot 3 began scouring. In a very few days this was stopped, and no more cases occurred. March 24 one-half of the cotton seed meal was replaced by linseed oil meal. The cotton seed meal in the ration was gradually replaced by oil meal. Neither the appetites of the steers nor their droppings appeared to be materially different as a result of this change. Their appetite fell off materially with the warm days of May and they were given less feed in consequence.

On the basis of the total digestible nutrients fed throughout the experiment, the nutritive ratio is 1: 7.64. This is too wide as compared with the standard nutritive ratio for fattening steers, a variation from the standard which is permissible in the corn belt where the effort is to use as much corn as possible, and the gains made for food consumed appear to indicate that a ration having a nutritive ratio of 1: 7.64 made up of the feeds used in this experiment will produce satisfactory returns.

Table 2 shows the daily rations fed per 1,000 pounds live weight in each lot by periods. This exhibit is presented because it is believed that many cattle feeders will be interested in knowing just how much and what kind of grain and how much and what variety of roughage the steers received daily during the various stages of the fattening process.

By referring to the table it will be seen that during the first month the number of pounds of roughage to grain or concentrates fed per thousand pound steer was as 4:3. From this time on the grain part of the ration was gradually increased while the roughage was as gradually decreased until the last, when about five times as much grain was fed as roughage.

Some timothy hay was fed, but for no other reason than that clover was not available at the time. The change from cotton seed to old process linseed meal was made to furnish greater variety.

Of the total feed consumed, a little less than 69 percent was grain and a little more than 31 percent was roughage; that is to say, the weight of roughage was 45 percent of that of the grain. As the same ration was fed to all there was no opportunity of knowing whether a different proportion would have been more favorable for certain of the grades.

TABLE 2.—DAILY RATION PER THOUSAND POUNDS LIVE WEIGHT BY PERIODS.

Lot	Food stuffs.	*Periods.						
		1	2	3	4	5	6	7
1	Cracked corn, and corn and cob meal.	8.75	13.38	19.19	17.63	16.91	16.74	17.12
	Cotton seed meal. ....	....	1.54	2.71	2.30	.98	....	....
	O. P. linseed meal. ....	....	....	....	....	1.23	2.34	2.39
	Alfalfa. ....	....	....	2.96	5.88	5.04	4.45	3.48
	Clover hay.	9.05	2.45	5.19	....	....	....	.20
	Timothy hay.	3.98	8.24	....	....	....	....	.30
	Corn stover. ....	....	2.50	1.10	....	....	....	....
2	Cracked corn and corn and cob meal.	8.63	13.38	19.35	18.54	18.98	18.27	17.99
	Cotton seed meal. ....	....	1.45	2.74	2.42	1.12	....	....
	O. P. linseed meal. ....	....	....	....	....	1.41	2.56	2.52
	Alfalfa. ....	....	....	2.94	6.18	5.75	4.85	3.65
	Clover hay.	8.91	2.36	5.25	....	....	....	.21
	Timothy hay.	4.22	7.95	....	....	....	....	.30
	Corn stover. ....	....	2.13	.96	....	....	....	....
3	Cracked corn and corn and cob meal.	9.43	13.90	19.35	18.58	19.10	18.11	17.89
	Cotton seed meal. ....	....	1.51	2.75	2.43	1.08	....	....
	O. P. linseed meal. ....	....	....	....	....	1.41	2.54	2.50
	Alfalfa. ....	....	....	2.96	6.20	5.67	4.81	3.56
	Clover hay.	10.12	2.46	5.20	....	....	....	.21
	Timothy hay.	3.88	8.40	....	....	....	....	.31
	Corn stover. ....	....	2.35	1.05	....	....	....	....
4	Cracked corn and corn and cob meal.	8.76	13.72	19.53	18.86	19.02	17.90	17.08
	Cotton seed meal. ....	....	1.52	2.80	2.47	1.10	....	....
	O. P. linseed meal. ....	....	....	....	....	1.39	2.51	2.39
	Alfalfa. ....	....	....	2.97	6.29	5.55	4.76	3.46
	Clover hay.	10.18	2.51	5.31	....	....	....	.20
	Timothy hay.	3.89	8.36	....	....	....	....	.29
	Corn stover. ....	....	2.37	1.07	....	....	....	....
5	Cracked corn and corn and cob meal.	9.01	13.81	19.50	18.35	18.37	17.11	17.60
	Cotton seed meal. ....	....	1.54	2.77	2.40	1.05	....	....
	O. P. linseed meal. ....	....	....	....	....	1.35	2.38	2.46
	Alfalfa. ....	....	....	2.95	6.12	5.46	4.54	3.57
	Clover hay.	10.90	2.51	5.26	....	....	....	.20
	Timothy hay.	4.03	8.48	....	....	....	....	.30
	Corn stover. ....	....	2.50	1.13	....	....	....	....
6	Cracked corn and corn and cob meal.	7.93	13.26	19.48	17.74	17.30	16.92	16.27
	Cotton seed meal. ....	....	1.52	2.71	2.32	.98	....	....
	O. P. linseed meal. ....	....	....	....	....	1.28	2.37	2.27
	Alfalfa. ....	....	....	2.94	5.91	5.14	4.50	3.29
	Clover hay.	10.15	2.45	5.37	....	....	....	.19
	Timothy hay.	4.63	8.23	....	....	....	....	.28
	Corn stover. ....	....	2.47	1.12	....	....	....	....

*Period 1 extended from November 29 to December 27, 1902; period 2, December 27, 1902, to January 24, 1903; period 3, January 24 to February 21; period 4, February 21 to March 21; period 5, March 21 to April 18; period 6, April 18 to May 16; period 7, May 16 to May 28.

TABLE 3.—EXTENT AND RAPIDITY OF GAINS IN POUNDS FOR THE VARIOUS GRADES.

Lot No.	Market grade at beginning of experiment.	16 steers at beginning of experiment.	Average per steer.	16 steers at end of experiment.	Average per steer.	Average gain per steer for whole period.	Average daily gain per steer for 179 days.
1	Fancy	14953	934.562	22315	1394.687	460.125	2.570
2	Choice	17836	1114.750	25120	1570.000	455.250	2.543
3	Good	16305	1019.062	23010	1438.125	419.062	2.341
4	Medium...	16355	1022.187	22450	1403.125	380.938	2.128
5	Common ..	15458	966.125	21780	1361.250	395.125	2.207
6	Inferior ...	15448	965.500	21055	1315.937	350.437	1.957

This table exhibits the total weight of each lot, and the average weight of each steer at the beginning and at the end of the experiment, the average gain of each steer in each lot for the whole period, and the average daily gain per steer in each lot throughout the feeding period.

Undoubtedly, the most characteristic thing illustrated in this table is the variation in the extent and rapidity of gains made by the steers in the various lots. With one exception it will be seen that the better the grade of steers the greater and the more rapid the gains. This exception is lot 4. The steers in lot 4 did not gain quite as rapidly as did those in lot 5 which were lower in grade. This variation in extent and rapidity of gains is so gradual and regular that it is added proof of the generally accepted fact that, where other conditions remain constant, the better the quality of steers the greater and the more rapid are the gains. That there should be such wide differences in gains as is shown in the above table adds further evidence on this point. The economic importance of this factor will receive comment later.

Larger gains are frequently reported, especially in short feeding periods, but at no time during the first half of the feeding period were these steers crowded to their utmost capacity. During the last half only were they given all that, in the judgment of those having the experiment in charge, they could use to advantage. Attention was given to economical rather than extensive production of beef. Economical production of beef involves the securing of a satisfactory market finish without overloading the animal with fat. While an over-ripe condition contributes largely to higher averages of dressed beef and higher percentages of fat, it is detrimental to the retail butcher, the consumer, and the producer; to the retail butcher because it entails too much waste of fat in cutting; to the consumer because he is forced to accept more fat at the market than can be agreeably consumed along with the lean beef accompanying the cut; and lastly, and most important of all from the feeders' standpoint, this unnecessary and superfluous fatness of the over-ripe bullock is the best possible evidence that the last gains have been very expensive.

TABLE 4.—AVERAGE DAILY GAIN PER STEER IN POUNDS FOR EACH LOT BY PERIODS AND AVERAGE FOR ALL LOTS BY PERIODS.

Lot No.	From Nov. 29–Dec. 27, 1902. 28 days.	From Dec. 27, 1902–Jan. 24, 1903. 28 days.	From Jan. 24–Feb. 21, 1903. 28 days.	From Feb. 21–Mar. 21, 1903. 28 days.	From Mar. 21–Apr. 18, 1903. 28 days.	From Apr. 18–May 16, 1903. 28 days.	From May 16–May 28, 1903. 12 days.	From Nov. 29, 1902–May 29, 1903. 179 days.
1	2.136	.959	3.024	2.812	2.968	3.303	3.125	2.570
2	2.095	.825	2.801	2.734	3.683	3.203	2.329	2.543
3	1.428	.904	2.555	2.500	3.448	2.801	3.380	2.341
4	1.484	.457	2.154	2.734	3.191	2.399	3.011	2.128
5	1.466	.424	2.232	2.714	3.538	2.544	3.039	2.207
6	1.466	.982	1.852	2.198	3.493	2.008	1.307	1.957
Average	1.679	.759	2.436	2.615	3.387	2.710	2.698	2.291

The accompanying Table 4 shows that the greatest average daily gain for the ninety-six head came during the four-week period from March 21 to April 18, and the lowest average daily gain was secured during the second four-week period. Barring the one exception of the second four weeks in the feeding period, taking the whole number of steers involved in this test, the average daily gains increased steadily from the first four-week period to that of the fifth period, after which the average daily gains fell off slightly for the last two periods, but the gains here were still greater than those obtained during any of the periods preceding period five. Tabulated records on subsequent pages of this Bulletin, Table 14, show that the committee of experts from the Yards, consisting of Messrs. Alexander, Shannon, and Brown, decided, without knowing the gains made by the cattle month by month, that during this same fifth period the steers increased in value more than during any other four-week period. This is evidence of the expert ability of these gentlemen and of the great care that was exercised in fixing the values of the cattle from month to month.

The results tabulated have a bearing upon the possible extent of gains in the various grades under study. By referring to Table 4 it will be seen that the average daily gains for the last forty days of the experiment were rather above than below the average for the whole time, an increase which indicates that probably fairly satisfactory gains could have been secured for a limited longer period. It is more than probable, however, that the increase in value per hundred weight of the steers of the various lots would not have been sufficient to render such feeding profitable. As bearing upon this important question we publish the following statement made by the committee of experts, Messrs. Alexander, Shannon, and Brown:

EXCHANGE BUILDING, UNION STOCK YARDS.

CHICAGO, Ill., September 10, 1903.

All of the various lots, from one to six, inclusive, of the steers mar-

keted by the Illinois Experiment Station, May 28th, 1903, were in good marketable condition. Their market value would not have been profitably enhanced by further feeding.

Signed,

{ JOHN T. ALEXANDER,
GEORGE W. SHANNON,
JAMES BROWN,

Committee of Experts.

TABLE 5.—ECONOMY OF GAINS AS MEASURED BY FEED CONSUMED. DIGESTIBLE
*DRY MATTER REQUIRED FOR PRODUCING GAINS IN BEEF,
COST OF POUND OF BEEF.

Lot No.	Total in concentrates.	Total in roughage.	Total dry matter.	Total gain, pounds.	Dry matter per pound of gain.	†Total cost of gain.	Cost per pound of gain.
1	50753.966	22513.674	73267.640	7362	9.952	\$496.45	\$0.0674
2	61393.255	26699.992	88093.247	7284	12.094	598.59	.0821
3	56236.152	24781.074	81017.226	6705	12.083	548.18	.0817
4	54977.196	24558.566	79535.762	6095	13.049	534.63	.0877
5	52179.942	23695.316	75875.258	6322	12.002	513.47	.0812
6	49512.307	22982.623	72494.930	5607	12.929	485.64	.0866
Total	325052.818	145231.245	470284.063	39375	11.943	3176.96	.0806

*Dry Matter. The portion of a feeding stuff remaining after the water or moisture contained therein has been driven off by heat. Ordinary feeds contain about 10 to 11 percent moisture.

†The figures in this column represent the total cost of feed less value of pork produced by the pigs following the various lots.

Table 5 exhibits not only the total number pounds digestible dry matter fed each lot, but the amount of dry matter in the roughage and in the concentrates separately. It shows the pounds dry matter required to produce a pound of gain in beef for each lot, the cost of gain, and the cost per pound of gain in each lot.

From the totals in this table it was determined that about 69.11 percent, or a little more than two-thirds of the digestible dry matter fed, was fed in the form of concentrates, such as corn and cob, cotton seed and oil meal, and 30.89 percent was fed in form of roughages, such as clover, timothy, alfalfa hay, and corn stover. It will be noticed that except in the case of lot 1 the total amount of dry matter consumed varies directly with the grade of steers. The better the grade, or the better bred the steers, the larger the consumption of dry matter. The consumption of dry matter did not follow as uniformly the variations in weight of the cattle. It did not necessarily follow that because one lot of steers was heavier than another it would consume more feed and consequently more dry matter. Weight certainly does have a marked influence upon capacity and demand for feed, but the records of this test appear to indicate that the possibility of large consumption is also dependent upon the grade or quality of the cattle. In case of lot

1, however, there appears to be a relatively small consumption of dry matter. This is the lot in which the weight of the cattle at the beginning of the experiment was much less than in other lots, and this undoubtedly was the cause of the smaller consumption of feed.

By referring to the column in the table showing the pounds dry matter required to produce a pound of gain in beef, it can be seen that while the average number of pounds of dry matter required to produce a pound of gain in beef for the whole 96 head involved in the experiment was 11.943 pounds, the steers in lot 1 required only 9.952 pounds. This shows that the steers in lot 1 were clearly the most economical producers of beef of all the lots. The gains in beef in lot 4 were made at greatest expense of dry matter consumed, while lot 6 is a close second. That there should be so much difference in the cost of a pound of beef between lot 1 and the other lots and that there should be such slight differences in the other grades should not be passed unnoticed. The cost of gains in the various lots does not seem to be clearly dependent upon either the age, initial weight, or breeding of the steers. In lot 1 we have the highest percentage of beef blood, the youngest age, and the least initial bodily weight. It is believed that all of these factors contributed to the results exhibited here. Evidence is wanting, however, to make it possible to make strong claims for any one of these factors as an essential above all things in the economic production of beef.

Cost of gains in beef were computed both on the basis of digestible dry matter consumed and net cost of food converted into beef. This will make it possible for the feeder to tell at a glance the relative cost of gains in beef in the various lots under conditions prevailing during the past season. Market prices of feeds used in beef production are subject to great variations, hence, the dry matter table is believed to be essential.

NUMBER OF POUNDS BEEF PRODUCED PER BUSHEL OF CORN FED.

Since it is customary among feeders to use a bushel of corn as the unit for figuring the possibility of securing certain gains from a given amount of feed, the subjoined statement will be of interest.

The steers in lot 1 made 9.74; lot 2, 7.97; lot 3, 7.99; lot 4, 7.45; lot 5, 8.13; and lot 6, 7.61 pounds of beef for each bushel of corn consumed.

It should be borne in mind that with each bushel of corn about eight pounds of some highly nitrogenous concentrate like cotton seed or linseed oil meal was fed, and that in addition to beef a certain amount of pork was produced.

TABLE 6.—NUMBER OF POUNDS DIGESTIBLE DRY MATTER REQUIRED TO PRODUCE A POUND OF GAIN FOR EACH PERIOD, ALSO FROM BEGINNING OF EXPERIMENT TO END OF EACH PERIOD.

Lot No.	Nov. 29- Dec. 27, 1902.	Dec. 27, 1902- Jan. 24, 1903.	Nov. 29, 1902- Jan. 24, 1903.	Jan. 24- Feb. 21, 1903.	Nov. 29, 1902- Feb. 21, 1903.	Feb. 21- Mar. 21, 1903.	Nov. 29, 1902- Mar. 21, 1903.	Mar. 21- Apr. 18, 1903.	Nov. 29, 1902- Apr. 18, 1903.	Apr. 18- May 16, 1903.	Nov. 29, 1902- May 16, 1903.	May 16- May 28, 1903.	Nov. 29, 1902- May 28, 1903.
1	8.60	24.815	13.630	9.654	11.669	9.464	10.472	8.408	10.024	8.408	10.024	9.058	9.952
2	10.342	32.891	16.715	12.081	14.447	11.678	13.552	9.354	12.278	10.740	11.957	14.385	12.094
3	14.733	28.557	20.091	12.021	15.872	11.611	14.490	9.080	12.727	11.046	12.382	9.008	12.083
4	13.890	55.704	23.743	14.191	18.720	10.667	15.496	9.590	13.615	12.463	13.393	9.438	13.049
5	13.951	57.585	23.739	12.992	17.867	9.982	14.738	8.091	12.471	11.244	12.229	9.349	12.002
6	13.242	24.407	17.200	15.614	16.813	11.799	15.117	7.649	12.507	13.370	12.651	19.423	12.929
All lots combined	12.066	33.091	18.609	12.468	15.540	10.810	13.891	8.774	12.294	10.977	12.032	10.776	11.943

Important data are presented in Table 6. It shows the amount of digestible dry matter required to produce a pound of gain during each of the four-week periods throughout the experiment and the amount required from the beginning of the experiment to the end of each period. From this data some light is thrown upon the question whether or not early gains are cheapest after eliminating the first few weeks during which time apparent gains are to be partially referred to "fill." The very large amount of dry matter required to produce a pound of gain in all the lots from December 27, 1902, to January 24, 1903, should be noted. By referring to Table 4 it will be seen that the gains in all the lots during this period were much smaller than the gains for the corresponding lots during the periods preceding and following the one in question. The fact that the gains were light during the preceding period is evidence that the small gains during the second period were not due to differences in stomach and intestinal contents at the beginning and end of the period. As far as we are able to determine, the expenditure of relatively so large an amount of dry matter to produce such small gains was due to several causes.

First, the feed lots were undergoing important changes which necessitated the frequent disturbance of the steers by workmen.

Second, visitors were numerous and the steers were frequently disturbed on their account.

Third, feeds which the steers had not been accustomed to eating were added to the ration, and the preparation of feeds used and method of feeding were considerably modified.

It has been customary in reporting tests of efficiency of feeds for meat production to reduce the results to the amount of feed required for producing a unit of gain. Thus the gain produced is assumed as the constant quantity and the amount of feed required is calculated on that basis. The author believes, however, that in discussing the efficiency of a ration a fixed quantity of the ration itself is properly the basis of calculations, and that the comparisons made should be between the different gains produced by this fixed quantity of the feed under the various conditions of the test. In this way the producing capacity of the feed is shown in simple terms, while by the other method the gaining capacity of the animal is the result obtained. On this assumption the following table is presented, showing the amount of beef produced per bushel of corn consumed, and the amount and value of the beef produced per 1,000 pounds digestible dry matter when fed to each of the six grades of steers.

The efficiency of the feed for producing increase in weight is shown in line 3 of the table, and is computed from the increase in weight and the digestible dry matter consumed by each lot of steers. The efficiency

in the case of lot 1 is then made the unit or 100 percent, and the results reduced to this basis, as shown in line 4.

Next the efficiency of the feed for producing increase in value per hundred weight of the beef is recorded in lines 7 and 8. These figures are derived as follows: Assuming a stationary market throughout the experiment, the increase in value per hundred weight of the cattle—as fixed by the committee of experts—is divided by the amount of digestible dry matter consumed (lines 5 and 6), giving the increase in value of cattle per hundred weight per unit of feed. Reducing the results to terms of lot 1 as above, we have the eighth line of the table.

Lines 9 and 10 show the efficiency of the feed for producing percent increase in value of cattle per hundred weight, which result is obtained for each lot by dividing the increase in value per hundred weight for 1,000 pounds digestible dry matter by the original cost per hundred weight.

In order to determine the efficiency of the feed for increasing both amount and quality of beef—in other words, to find the total increase in value of the cattle due to a unit of feed consumed—the increase in live weight per unit of feed is multiplied by the increase in value per hundred weight per 1,000 pounds digestible dry matter consumed. In this way lines 11 and 12 are obtained.

Taking into consideration the percent increase in value per hundred weight of the cattle and their increase in weight, for 1,000 pounds digestible dry matter consumed, the net efficiency of the feed may be computed. This result is shown in lines 13 and 14, which are obtained by multiplying the results in line 2 by the corresponding numbers in line 9. We now have the efficiency of the feed with respect to increase in weight (line 4), increase in value per hundred weight (line 8), percent increase in value per hundred weight (line 10); increase in value (line 12); and percent increase in value combined with increase in weight (line 14).

It should be borne in mind that the data presented in the accompanying table are computed on the basis of a stationary market, the increases in value per hundred weight in the various grades being fixed by the committee of experts.

TABLE 7.

	Lot 1, Fancy.	Lot 2, Choice.	Lot 3, Good.	Lot 4, Medium.	Lot 5, Common.	Lot 6, Inferior.	Line.
Lb. beef produced per bu. corn consumed ...	9.74	7.97	7.99	7.45	8.13	7.61	(1)
Lb. beef produced per 1,000 lb. digestible dry matter consumed.....	100.40	82.60	82.70	76.60	83.30	77.30	(2)
Efficiency of feed for producing quantity of gain, or percent of digestible dry matter converted into beef ...	10.04	8.26	8.27	7.66	8.33	7.73	(3)
Efficiency of feed for quantity of gain on basis of 100 percent for lot 1.....	100	82	82	76	83	77	(4)
Increase in value of cattle per cwt.....	\$2.25	\$2.35	\$2.30	\$1.95	\$1.90	\$2.05	(5)
Total lb. digestible dry matter consumed ...	73,268	88,093	81,017	79,536	75,875	72,495	(6)
Increase in value of cattle per cwt. per 1,000 lb. of digestible dry matter consumed.....	\$0.031	\$0.027	\$0.028	\$0.025	\$0.025	\$0.028	(7)
Increase in value of cattle per cwt. per 1,000 lb. digestible dry matter consumed on basis of 100 for lot 1	100	87	90	81	81	90	(8)
Percent increase in value of cattle per cwt. per 1,000 lb. digestible matter consumed.....	.0065	.0059	.0066	.0065	.0069	.0083	(9)
Ditto on basis of 100 percent for lot 1.....	100	91	102	100	106	128	(10)
Increase in total value of cattle per 1,000 lb. digestible dry matter consumed	\$3.11	\$2.23	\$2.32	\$1.91	\$2.08	\$2.16	(11)
Ditto on basis of 100 for lot 1.....	100	72	75	61	67	69	(12)
Percent increase in value per hundred weight combined with increase in weight for 1000 lb. digestible dry matter consumed	.652	.487	.545	.497	.574	.541	(13)
Ditto on basis of 100 for lot 1.....	100	75	84	76	88	98	(14)

With respect to amount of gain produced the feed of lots 1, 2, 3, 4, 5, and 6 was effective or efficient in the ratio 100 82, 82, 76, 83, 77 respectively.

With respect to quality of the increase, or its increase in value per hundred weight, the ratio was 100, 87, 90, 81, 81, 90.

With respect to the percent increase in value per hundred weight the ratio was 100, 91, 102, 100, 106, 128.

With respect to combined quantity and quality of gains, or total increase in value of the cattle, the ratio was 100, 72, 75, 61, 67, 69.

With respect to percent increase in value per hundred weight combined with increase in weight the ratio was 100, 75, 84, 76, 88, 98.

It will be observed that the most economical disposition of the feed consumed was made by the fancy selected feeders, excepting as to their percent increase in value per hundred weight for feed consumed. As previously noted, these steers were younger, lighter, and of more uniform breeding than any of the other grades. Another notable fact is that the feed was clearly more efficient for increasing the value of the cattle in the three higher than in the three lower grades when both quantity and quality of gains are considered. The good showing made by the common and inferior cattle in respect to the percent increase in value per hundred weight for a given quantity of feed, and in respect to the percent increase in value per hundred weight combined with their increase in weight as indicated in lines 10 and 14, respectively, is due to their lower original cost and consequent advantage as to relative or percent increase in value. The efficiency of the feed as shown by the percent increase in value per hundred weight of cattle is a more variable factor than its efficiency as indicated by the actual gain in weight and its value per hundred weight, so that the result in line 12 can be accepted as a more constant and reliable comparison of the grades than can those of lines 10 and 14, because any market condition which changes cost, selling price, relative increase in value per hundred weight of the various grades would materially change the relative percent increase in value of the cattle. These results as a whole may be interpreted as pointing to a relatively more economical gain by the higher grades, and a widely variable relation between the various grades as to the percent of increase in actual value which they will produce from a given amount of feed. The feed was least efficient as to value per hundred weight of gains when fed to the medium and common grades, least efficient as to combined quantity and quality of gains when fed to the medium cattle; and least efficient as to percent increase in value per hundred weight combined with increase in weight in the case of the choice and medium grades.

GAINS IN WEIGHT OF PIGS FOLLOWING STEERS.

As has been stated elsewhere it was thought advisable to eliminate the pig as far as possible in this test. This end was reached by grinding the grain. Five pigs were placed with each lot of sixteen steers at the beginning of the experiment. As will be seen by referring to the following statement the steers received very light grain rations for the first two months and made correspondingly small increase in live weight. One of the pigs in lot 5 was accidentally killed and as no other pig was

available to substitute in its place it was thought best to reduce the number in each lot to correspond with that in lot 5. During the last month of the experiment eight pigs were allowed to follow the sixteen steers in lot 2. These eight pigs made nearly as great average individual gains as when only four were following the sixteen steers. From this we are led to believe that from the time the steers were worked up to full feed until the end of the experiment, the production of pork might have been nearly doubled. It should not be assumed that the large pork production of the pigs in lot 2 during the last month was due to the fact that the droppings had been allowed to accumulate for a long time as the pens were cleaned but shortly before the extra pigs were turned into them.

The gains in pork by lots for the whole period were as follows:

Lot 1. 419 pounds.	Lot 4. 520 pounds.
*Lot 2. 500 pounds.	Lot 5. 420 pounds.
Lot 3. 475 pounds.	Lot 6. 480 pounds.

It is quite remarkable that the smallest amount of pork produced should be in the lot where the steers took the least number of pounds of dry matter to produce a pound of beef, and that where pork production was greatest the feed was apparently least efficient for beef production. The relationship between the high efficiency of the feed for beef production and minimum pork production is too regular to escape comment. Referring to the table exhibiting the average number of pounds of dry matter to produce a pound of gain in beef (Table 5), it will be seen that for efficiency, the lots stand in the following order: 1, 5, 3, 2, 6, and 4, while for pork production, they have the following order, beginning with the lot showing smallest production of pork: 1, 5, 3, 6, 2, and 4.

The steers were loaded for shipment to Chicago on Wednesday afternoon May 27, care being taken to have each lot receive as nearly the same treatment as possible. The Champaign weight was taken on the morning of the 27th before the cattle had been fed or watered. They were then fed their regular feed of grain and roughage, except that the roughage fed on the morning of the 27th and that fed on the previous day was timothy hay instead of clover or alfalfa, which are liable to cause some bloating in transit. In case the roughage fed consists of clover or alfalfa bloating can usually be avoided by the feeding of timothy hay for the last day or two before shipment. The steers were also given free access to water between 9 and 10 A. M. after being grained.

*The actual amount of pork produced by the original four pigs following this lot of steers throughout the experiment, thus making it possible to compare the pork produced in this lot with that produced in all other lots.

TABLE 8.—NATURE OF GAINS. SHIPPING AND SLAUGHTER WEIGHTS OF STEERS.

	Lot 1.	Lot 2.	Lot 3.	Lot 4.	Lot 5.	Lot 6.
Weight 16 steers, Champaign, May 27, 1903. Pounds	22315.00	25120.00	23010.00	22450.00	21780.00	21055.00
Average weight per steer, Champaign. Pounds	1394.68	1570.00	1438.12	1403.12	1361.25	1315.93
Weight 16 steers, Chicago, May 28, 1903	21960.00	24650.00	22430.00	21980.00	21370.00	20940.00
Average weight per steer, Chi- cago. Pounds ..	1372.50	1540.62	1401.87	1373.75	1335.62	1308.75
Percentage of shrinkage in shipping	1.59	1.87	2.08	1.64	1.88	.54
Pounds shrinkage per steer	22.18	29.37	36.25	29.27	25.62	7.18
Total dressed weight of 16 carcasses	13532.00	15165.00	13622.00	13120.00	12797.00	12341.00
Average weight of 16 carcasses. Pounds	846.00	947.00	851.00	820.00	799.00	777.00
Percentage of car- cass to live weight	61.62	61.52	60.74	59.70	59.88	59.36
Percentage of caul fat	3.39	3.50	3.59	3.77	3.61	3.83
Percentage of rough fat ...	6.07	6.18	6.98	6.98	6.46	7.98

Especial care was taken to bed the cars well with straw, and for convenience in keeping the lots separate only sixteen steers were put in a car. The yards and loading chutes at Champaign were located about a mile from the feed lots. In driving the cattle to the loading chutes and in loading them, great care was exercised to handle them quietly and without confusion, that they might arrive on the market with as little shrinkage as possible. The cattle were all loaded between three and six o'clock in the afternoon. They left Champaign at 7:30 P. M., May 27, and arrived in Chicago at 5:30 A. M., May 28.

By referring to the above table it will be seen that the shrinkage per steer was light with all the lots, but remarkably so with lot 6. The highest shrinkage was with lot 3. The light shrink of the steers in lot 6 is undoubtedly due to the fact that they "filled" better in the Yards than the steers in the other lots, especially much better than those in lot 3. No cause is known why lot 3 should "fill" the poorest and lot 6 the best. With the two exceptions noted, the percentages of shrinkage were quite uniform. The light shrinkage is attributed partly to the quiet handling in driving and loading, and partly to the feeding of timothy hay during the last two days. No attempt was made to handle the cattle in such

a way as to secure a "big fill" at the Union Stock Yards, as it was desirable that there should be nothing to interfere with the normal percentages of dressed beef in each lot and the normal relation existing between the percentages of dressed beef in the various lots.

In referring to the above table it may be said that the most striking fact brought out by it is that the percentages of dressed beef bear precisely the same relation to each other as do the gains in live weight. The steers in lot 1 gained the most, lot 2 came next, with lots 3, 5, 4, and 6 following in the order named. The steers in lot 1 dressed the highest, 61.62 percent, those in lot 2 came next, with lots 3, 5, 4 and 6 following in the order named.

These higher percentages in the higher grades were not altogether due to any advantage in condition which the better grades had over the poorer ones, but were due partly at least to the differences in quality in the different grades. It is very doubtful whether lots 1, 2, 3, and 4 were really in as high market condition as were lots 5 and 6. It is another question of course whether or not inferior or common steers are capable of taking on as high finish and absolute fatness as the better grades.

It will be noted that the percentages of caul fat were highest in the poorer grades, being highest in lot 6 and lowest in lot 1. Again lot 1 had the least rough fat, while lot 6 had the most. The carcasses showed conclusively that while the lower grades had the most internal fat, the higher, or better grades, carried thicker surface fat.

While unquestionably the condition of an animal has great influence upon the percentage of dressed beef it will yield, quality appears to be an important factor as well. It could not be said therefore, that the percentages of dressed beef were low in the poorer grades because they were not as well finished, or in other words, not in as high condition as were lots 1, 2, and 3, for neither the appearance of the steers on foot nor their carcasses after slaughter gave any evidence of an unfinished condition in these grades. If there was an advantage in the condition of the steers it was in favor of lots 4, 5, and 6, which were doubtless nearer their maximum limit as to finish than were the better grades, lots 1, 2, and 3.

The following table shows that as a result of feeding the 16 *fancy* feeders in lot 1 until finished, there was only one steer that would not grade as prime. This steer lacked slightly in quality, but principally in condition, and he graded as choice. After slaughtering, the beef experts in Armour & Company's city beef department graded all the carcasses as No. 1.

TABLE 9.—MARKET GRADES AS FEEDERS, FAT CATTLE, AND BEEF.

	Market grade at beginning of experiment as feeders.	Market grade at end of experiment as fat cattle.	Market grade of beef after slaughtering.
Lot No.	Name of grade and number of steers in each grade.	Grade and number of steers in each grade.	Name of grade and number of carcasses in each grade.
1	Fancy, 16	{ Prime, 15 } { Choice, 1 }	No. 1, 16
2	Choice, 16	{ Prime, 14 } { Choice, 1 } { Good, 1 }	No. 1, 16
3	Good, 16	{ Prime, 3 } { Choice, 5 } { Good, 8 }	No. 1, 16
4	Medium, 16	{ Choice, 1 } { Good, 4 } { Medium, 8 } { Common, 3 }	No. 1, Light, 4 No. 2 Tops, 12
5	Common, 16	{ Good, 5 } { Medium, 6 } { Common, 5 }	No. 1 Light, 4 No. 2 Tops, 12
6	Inferior, 16	{ Good, 4 } { Medium, 6 } { Common, 6 }	No. 1 Light, 6 No. 2 Tops, 9 No. 3, 1

Of the 16 *choice* feeders (lot 2) fourteen finished as prime, one as choice, and one as good. All the carcasses graded as No. 1 beef.

Of the 16 *good* feeders (lot 3) three finished as prime, five as choice, and eight as good. All the carcasses graded as No. 1.

Of the 16 *medium* feeders (lot 4) one finished as choice, four as good, eight as medium, and three as common. Four of the carcasses in this lot graded as No. 1 light, and the remainder as No. 2 tops.

Of the 16 *common* feeders (lot 5) five finished the test as good, six as medium, and five as common beeves. The grading of the beef was the same as that in lot 4, namely, four carcasses graded as No. 1 light, and twelve as No. 2 tops.

Of the 16 *inferior* feeders (lot 6) four finished as good, six as medium, and six as common. Six carcasses graded as No. 1 light, nine as No. 2 tops, and one as No. 3 beef.

Both this and the preceding table illustrate forcibly the possibility of securing reasonably high percentages of dressed beef of satisfactory grades even with low bred steers if intelligently fed to as high a finish as they are capable of taking.

The records of this experiment all emphasize the great economic importance of condition as a factor in marketing and in determining the grade of beef. It is possible that we have not emphasized this factor enough. Perhaps in the campaign that has been waged to improve the quality of beef cattle, condition has failed to receive the attention which its importance demands. This is but a natural result of confining inves-

tigations in beef production to the live animal. It is safe to say that there are more differences between the well-bred steer and the mongrel-bred feeding steer when on foot in the feed lot than there are after they are fed to a finish, slaughtered, and hung on the hooks.

When fat-cattle prices rule high and there is a tendency for the prices for such cattle to advance, there is a wide range in values between the highest grade of beef cattle, namely, prime steers, and the lowest grade, common rough steers. In other words, a premium is then paid for cattle possessing prime quality or a high percentage of beef blood.

THE FINANCIAL ASPECT OF THE EXPERIMENT.

Many feeders will be interested in the following financial statement. This phase of the subject will be discussed from two standpoints on the basis of:

First, a steady or stationary market, obviously the one which should be looked upon as a normal one, with which other market conditions should be compared.

Second, a falling or declining market.

COST OF FEEDS.

The feeds used were cracked corn (prepared by running ears through an ensilage machine which cut the cobs up into small pieces and cracked the corn), corn and cob meal, cotton seed meal, old process linseed oil meal, clover hay, alfalfa, timothy hay, and corn stover.

These feeds were valued f. o. b. cars, Champaign, Illinois, as follows:

Cracked corn and corn and cob meal....	*\$12.00 per ton
Cotton seed meal	24.50 per ton
O. P. linseed oil meal	25.00 per ton
Clover hay	8.00 per ton
Alfalfa	10.00 per ton
Timothy hay	12.00 per ton
Corn stover	3.00 per ton

From the time the experiment began until the evening of February 15, the corn used was rather soft and chaffy; it would be called very poor in quality and not well adapted for securing large gains for amount consumed. For convenience, all the corn is figured at the same price.

No charge is made in the financial statement for labor in caring for the steers, interest on the investment, or for bedding, nor on the other hand, is any value assigned to the manure made by the steers. It is believed that the manure would more than balance these expense items.

*\$12.00 per ton, or 35 cents per bushel of 70 pounds plus 10 cents per cwt. for grinding.

FINANCIAL STATEMENT ON BASIS OF NORMAL OR STATIONARY MARKET.

Lot 1, 16 Steers.

To 16 Steers, 14,953 lb., at \$4.75 per cwt.	\$ 710.27
26.447 tons cracked corn, and corn and cob meal at \$12 per ton	317.36
1.914 tons cotton seed meal, at \$24.50 per ton	46.89
1.358 tons O. P. linseed oil meal at \$25.00 per ton	33.95
3.885 tons clover hay, at \$8.00 per ton	31.08
5.500 tons alfalfa, at \$10 per ton	55.00
2.810 tons timothy hay, at \$12 per ton	33.72
.845 tons corn stover, at \$3 per ton	2.54
Freight Champaign to Chicago, commission, yardage, feed, and other expenses	40.00
Total expenditures	\$1270.81
By 16 Steers, 21,960 lb., at \$7 per cwt	\$1537.20
By 419 lb. Pork, at \$5.75 per cwt.	24.09
Total receipts	\$1561.29
Total expenditures	1270.81
Total gain	\$ 290.48
Profit per steer	18.155

Lot 2, 16 Steers.

To 16 Steers, 17,836 lb., at \$4.55 per cwt.	\$ 811.54
31.983 tons cracked corn and corn and cob meal, at \$12.00 per ton	383.80
2.270 tons cotton seed meal, at \$24.50 per ton	55.62
1.692 tons O. P. linseed oil meal, at \$25.00 per ton	42.30
4.503 tons clover hay, at \$8.00 per ton	36.02
6.769 tons alfalfa, at \$10.00 per ton	67.69
3.281 tons timothy hay, at \$12.00 per ton	39.37
.845 tons corn stover, at \$3.00 per ton	2.54
Freight Champaign to Chicago, commission, yardage, feed, and other expenses	40.00
Total expenditures	\$1478.88
By 16 Steers, 24,650 lb., at \$6.90 per cwt.	\$1700.85
By 500 lb. Pork, at \$5.75 per cwt.	28.75
Total receipts	\$1729.60
Total expenditures	1478.88
Total gain	\$ 250.72
Profit per steer	15.67

Lot 3, 16 Steers.

To 16 Steers, 16,305 lb., at \$4.20 per cwt.	\$ 684.81
29.335 tons cracked corn and corn and cob meal, at \$12.00 per ton	352.02
2.066 tons cotton seed meal, at \$24.50 per ton	50.62
1.530 tons O. P. linseed oil meal, at \$25.00 per ton	38.25
4.372 tons clover hay, at \$8.00 per ton	34.98
6.109 tons alfalfa, at \$10.00 per ton	61.09
2.999 tons timothy hay, at \$12.00 per ton	35.99
.845 tons corn stover, at \$3.00 per ton	2.54
Freight Champaign to Chicago, commission, yardage, feed, and other expenses	40.00
Total expenditures	\$1300.30
By 16 Steers, 22,430 lb., at \$6.50 per cwt.	\$1457.95
By 475 lb. Pork, at \$5.75 per cwt.	27.31
Total receipts	\$1485.26
Total expenditures	1300.30
Total gain	\$ 184.96
Profit per steer	11.56

Lot 4, 16 Steers.

To 16 Steers, 16,355 lb., at \$3.85 per cwt.....	\$ 629.67
28.651 tons cracked corn and corn and cob meal, at \$12.00 per ton...	343.81
2.069 tons cotton seed meal, at \$24.50 per ton	50.69
1.470 tons O. P. linseed oil meal, at \$25.00 per ton.....	36.75
4.410 tons clover hay, at \$8.00 per ton	35.28
5.969 tons alfalfa, at \$10.00 per ton.....	59.69
2.981 tons timothy hay, at \$12.00 per ton.....	35.77
.845 tons corn stover, at \$3.00 per ton.....	2.54
Freight Champaign to Chicago, commission, yardage, feed, and other expenses	40.00

Total expenditures\$1234.20

By 16 Steers, 21,980 lb., at \$5.80 per cwt.....\$1274.84

By 520 lb. Pork, at \$5.75 per cwt.....29.90

Total receipts.....\$1304.74

Total expenditures1234.20

Total gain.....\$ 70.54

Profit per steer4.41

Lot 5, 16 Steers.

To 16 Steers, 15,458 lb., at \$3.60 per cwt.....	\$ 556.49
27.204 tons cracked corn and corn and cob meal, at \$12.00 per ton...	326.45
1.941 tons cotton seed meal, at \$24.50 per ton.....	47.55
1.409 tons of O. P. linseed oil meal, at \$25.00 per ton.....	35.23
4.332 tons clover hay, at \$8.00 per ton	34.66
5.662 tons of alfalfa hay, at \$10.00 per ton	56.62
2.881 tons of timothy hay, at \$12.00 per ton.....	34.57
.845 tons corn stover, at \$3.00 per ton.....	2.54
Freight, Champaign to Chicago, commission, yardage, feed, and other expenses	40.00

Total expenditures\$1134.11

By 16 Steers, 21,370 lb., at \$5.50 per cwt.....\$1175.35

By 420 lb. Pork, at \$5.75 per cwt.....24.15

Total receipts.....\$1199.50

Total expenditures1134.11

Total gain.....\$ 65.39

Profit per steer4.09

Lot 6, 16 Steers.

To 16 Steers, 15,448 lb., at \$3.35 per cwt.....	\$ 517.51
25.801 tons cracked corn and corn and cob meal, at \$12.00 per ton ...	309.61
1.871 tons cotton seed meal, at \$24.50 per ton.....	45.84
1.311 tons O. P. linseed oil meal, at \$25.00 per ton.....	32.78
4.132 tons clover hay, at \$8.00 per ton.....	33.06
5.361 tons alfalfa hay, at \$10.00 per ton.....	53.61
2.983 tons timothy hay, at \$12.00 per ton.....	35.80
.845 tons corn stover, at \$3.00 per ton.....	2.54
Freight, Champaign to Chicago, commission, yardage, feed, and other expenses	40.00

Total expenditures\$1070.75

By 16 Steers, 20,940 lb., at \$5.40 per cwt.....\$1130.76

By 480 lb. Pork, at \$5.75 per cwt.....27.60

Total receipts.....\$1158.36

Total expenditures1070.75

Total gain.....\$ 87.61

Profit per steer5.48

From the above it will be seen that under normal conditions, that is when the market remains stationary, the best grades of feeding cattle return to the feeder the greatest profit. So striking is this fact that in the preceding financial statement the fancy feeders, on the basis of a stationary market, would have returned to the feeder over three times as much per steer as the inferior feeders. It is well for the cattle feeder to consider the factors which make it possible to make such a showing. Such a favorable showing for the better grade of feeding cattle could not be made if the margins between the price of choice feeders and prime steers were not so large as those between inferior feeders and common rough and medium steers of the beef cattle class.

Profits may be realized on smaller margins in the finishing of the better than the lower grades of feeders. With the higher initial cost of the better grades the cost of feed becomes relatively of less consequence. This being the case it has been found to be almost an invariable rule that the higher the price of feeds, the more sure are the better grades to return to the cattle feeder larger profits than the feeding of the poorer grades. When the cattle market is in any thing like a normal condition, the margins are as great, if not on the average greater, with the better than with the lower grades.

Tables 11 and 12 will be found of unusual interest to the student of the cattle feeding enterprise. These tables show the financial status of the various lots at the end of the first fifty-six days and every four weeks thereafter, except in case of the last period which was but eleven days. It will be observed that this statement is made not only upon the basis of a normal or stationary market, but also on the basis of an abnormal or a falling market, such as obtained during the winter season of 1902-1903. It is thought that a statement at the end of the first thirty days would be of little value, as no one would seriously consider marketing cattle such as were used in this experiment, at the end of thirty days' light grain feeding. In the several columns in Table 11 is recorded the cost of the steers in the various lots up to the dates as given in the marginal columns. This cost includes the initial market value of the cattle, the cost of feed, and the estimated expense of marketing. These items are entered separately that the reader may determine for himself which are items of greatest importance in the various lots and at stated intervals during the progress of the experiment.

To make the financial statements of the several periods comparable in the following statement, it was necessary to use Champaign instead of Chicago weights at the end of the experiment. This explains the apparent discrepancy between the statement of profits shown on pages 182, 183, and 190, as Chicago and not Champaign weights were used in computing profits shown on pages 182 and 183.

TABLE 11.—FINANCIAL STATEMENT AT DIFFERENT DATES ON BASIS OF BOTH FALLING AND STATIONARY MARKET CONDITIONS. CHAMPAIGN WEIGHTS.

Financial statement end of 56 days, Nov. 29, 1902, to Jan. 24, 1903.	DISBURSEMENTS.		MARKET PRICE PER CWT.		RECEIPTS.	
	Station- ary.	Falling.	Station- ary.	Falling.	Station- ary.	Falling.
Lot 1, 16 Steers.						
To 14953 lb. at \$4.75 ...	\$710.27	\$710.27				
Feed, 56 days	124.29	124.29				
Freight, etc.	40.00	40.00				
By 16340 lb. beef			\$5.25	\$5.00	\$857.85	\$817.00
105 lb. pork					6.04	6.04
Falling market, loss						51.52
Stationary market, loss					10.67	
	874.56	874.56			874.56	874.56
Lot 2, 16 Steers.						
To 17836 lb. at \$4.55 ...	811.54	811.54				
Feed, 56 days	144.14	144.14				
Freight, etc.	40.00	40.00				
By 19145 lb. beef			5.10	4.80	976.40	918.96
190 lb. pork					10.93	10.93
Falling market, loss						65.79
Stationary market, loss					8.35	
	995.68	995.68			995.68	995.68
Lot 3, 16 Steers.						
To 16305 lb. at \$4.20 ...	684.81	684.81				
Feed, 56 days	137.56	137.56				
Freight, etc.	40.00	40.00				
By 17350 lb. beef			4.60	4.40	798.10	763.40
130 lb. pork					7.48	7.48
Falling market, loss						91.49
Stationary market, loss					56.79	
	862.37	862.37			862.37	862.37
Lot 4, 16 Steers.						
To 16355 lb. at \$3.85 ...	629.67	629.67				
Feed, 56 days	135.02	135.02				
Freight, etc.	40.00	40.00				
By 17225 lb. beef			4.25	4.15	732.06	714.84
160 lb. pork					9.20	9.20
Falling market, loss						80.65
Stationary market, loss					63.43	
	804.69	804.69			804.69	804.69
Lot 5, 16 Steers.						
To 15458 lb. at \$3.60 ...	556.49	556.49				
Feed, 56 days	130.97	130.97				
Freight, etc.	40.00	40.00				
By 16305 lb. beef			4.10	3.90	668.51	635.90
130 lb. pork					7.48	7.48
Falling market, loss						84.08
Stationary market, loss					51.47	
	727.46	727.46			727.46	727.46
Lot 6, 16 Steers.						
To 15448 lb. at \$3.35 ...	517.51	517.51				
Feed, 56 days	126.89	126.89				
Freight, etc.	40.00	40.00				
By 16545 lb. beef			3.85	3.65	636.98	603.89
115 lb. pork					6.61	6.61
Falling market, loss						73.90
Stationary market, loss					40.81	
	684.40	684.40			684.40	684.40

TABLE 11—Continued.

Financial statement end of 84 days, Nov. 29, 1902, to Feb. 21, 1903.	DISBURSEMENTS.		MARKET PRICE PER CWT.		RECEIPTS.	
	Station- ary.	Falling.	Station- ary.	Falling.	Station- ary.	Falling.
Lot 1, 16 Steers.						
To 14953 lb. at \$4.75 ...	\$710.27	\$710.27				
Feed, 84 days	216.22	216.22				
Freight, etc.	40.00	40.00				
By 17695 lb. beef			\$5.55	\$5.00	\$982.07	\$884.75
185 lb. pork					10.64	10.64
Falling market, loss						71.10
Stationary market, profit	26.22					
	992.71	966.49			992.71	966.49
Lot 2, 16 Steers.						
To 17836 lb. at \$4.55 ...	811.54	811.54				
Feed, 84 days	250.94	250.94				
Freight, etc.	40.00	40.00				
By 20400 lb. beef			5.55	4.80	1132.20	979.20
285 lb. pork					16.38	16.38
Falling market, loss						106.90
Stationary market, profit	46.10					
	1148.58	1102.48			1148.58	1102.48
Lot 3, 16 Steers.						
To 16305 lb. at \$4.20 ...	684.81	684.81				
Feed, 84 days	234.44	234.44				
Freight, etc.	40.00	40.00				
By 18495 lb. beef			5.10	4.65	943.25	860.02
220 lb. pork					12.65	12.65
Falling market, loss						86.58
Stationary market, loss					3.35	
	959.25	959.25			959.25	959.25
Lot 4, 16 Steers.						
To 16355 lb. at \$3.85 ...	629.67	629.67				
Feed, 84 days	231.38	231.38				
Freight, etc.	40.00	40.00				
By 18190 lb. beef			4.65	4.50	845.84	818.55
255 lb. pork					14.66	14.66
Falling market, loss						67.84
Stationary market, loss					40.55	
	901.05	901.05			901.05	901.05
Lot 5, 16 Steers.						
To 15458 lb. at \$3.60 ...	556.49	556.49				
Feed, 84 days	222.29	222.29				
Freight, etc.	40.00	40.00				
By 17305 lb. beef			4.35	4.40	752.77	761.42
210 lb. pork					12.08	12.08
Falling market, loss						45.28
Stationary market, loss					53.93	
	818.78	818.78			818.78	818.78
Lot 6, 16 Steers.						
To 15448 lb. at \$3.35 ...	517.51	517.51				
Feed, 84 days	217.90	217.90				
Freight, etc.	40.00	40.00				
By 17375 lb. beef			4.35	4.40	755.81	764.50
205 lb. pork					11.79	11.79
Stationary market, loss					7.81	
Falling market, profit		.88				
	775.41	776.29			775.41	776.29

TABLE 11—Continued.

Financial statement end of 112 days, Nov. 29, 1902, to March 21, 1903.	DISBURSEMENTS.		MARKET PRICE PER CWT.		RECEIPTS.	
	Station- ary.	Falling.	Station- ary.	Falling.	Station- ary.	Falling.
Lot 1, 16 Steers.						
To 14953 lb. at \$4.75 ...	\$710.27	\$710.27				
Feed, 112 days	302.98	302.98				
Freight, etc.	40.00	40.00				
By 18955 lb. beef			\$5.90	\$5.20	\$1118.35	\$985.66
250 lb. pork					14.38	14.38
Falling market, loss						53.21
Stationary market, profit	79.48					
	1132.73	1053.25			1132.73	1053.25
Lot 2, 16 Steers.						
To 17836 lb. at \$4.55 ...	811.54	811.54				
Feed, 112 days	354.99	354.99				
Freight, etc.	40.00	40.00				
By 21625 lb. beef			5.90	5.05	1275.88	1092.06
315 lb. pork					18.11	18.11
Falling market, loss						96.36
Stationary market, profit	87.46					
	1293.99	1206.53			1293.99	1206.53
Lot 3, 16 Steers.						
To 16305 lb. at \$4.20 ...	684.81	684.81				
Feed, 112 days	329.02	329.02				
Freight, etc.	40.00	40.00				
By 19615 lb. beef			5.45	4.75	1069.02	931.71
285 lb. pork					16.39	16.39
Falling market, loss						105.73
Stationary market, profit	31.58					
	1085.41	1053.83			1085.41	1053.83
Lot 4, 16 Steers.						
To 16355 lb. at \$3.85 ...	629.67	629.67				
Feed, 112 days	326.42	326.42				
Freight, etc.	40.00	40.00				
By 19415 lb. beef			5.05	4.65	980.46	902.80
310 lb. pork					17.82	17.82
Falling market, loss						75.47
Stationary market, profit	2.19					
	998.28	996.09			998.28	996.09
Lot 5, 16 Steers.						
To 15458 lb. at \$3.60 ...	556.49	556.49				
Feed, 112 days	310.49	310.49				
Freight, etc.	40.00	40.00				
By 18520 lb. beef			4.55	4.50	842.66	833.40
235 lb. pork					13.51	13.51
Falling market, loss						60.07
Stationary market, loss ..					50.81	
	906.98	906.98			906.98	906.98
Lot 6, 16 Steers.						
To 15448 lb. at \$3.35 ...	517.51	517.51				
Feed, 112 days	302.44	302.44				
Freight, etc.	40.00	40.00				
By 18360 lb. beef			4.65	4.50	853.74	826.20
240 lb. pork					13.80	13.80
Falling market, loss						19.95
Stationary market, profit	7.59					
	867.54	859.95			867.54	859.95

TABLE 11—Continued.

Financial statement end of 140 days, Nov. 29, 1902, to April 18, 1903.	DISBURSEMENTS.		MARKET PRICE PER CWT.		RECEIPTS.	
	Station- ary.	Falling.	Station- ary.	Falling.	Station- ary.	Falling.
Lot 1, 16 Steers.						
To 14953 lb. at \$4.75 . . .	\$710.27	\$710.27				
Feed, 140 days	390.46	390.46				
Freight, etc.	40.00	40.00				
By 20285 lb. beef			\$6.25	\$5.40	\$1267.81	\$1095.39
325 lb. pork					18.69	18.69
Falling market, loss						26.65
Stationary market, profit	145.77					
	1286.50	1140.73			1286.50	1140.73
Lot 2, 16 Steers.						
To 17836 lb. at \$4.55 . . .	811.54	811.54				
Feed, 140 days	468.30	468.30				
Freight, etc.	40.00	40.00				
By 23275 lb. beef			6.30	5.45	1466.33	1268.49
380 lb. pork					21.85	21.85
Falling market, loss						29.50
Stationary market, profit	168.34					
	1488.18	1319.84			1488.18	1319.84
Lot 3, 16 Steers.						
To 16305 lb. at \$4.20 . . .	684.81	684.81				
Feed, 140 days	431.97	431.97				
Freight, etc.	40.00	40.00				
By 21160 lb. beef			5.95	5.15	1259.02	1089.74
340 lb. pork					19.55	19.55
Falling market, loss						47.49
Stationary market, profit	121.79					
	1278.57	1156.78			1278.57	1156.78
Lot 4, 16 Steers.						
To 16355 lb. at \$3.85 . . .	629.67	629.67				
Feed, 140 days	427.20	427.20				
Freight, etc.	40.00	40.00				
By 20845 lb. beef			5.45	5.00	1136.05	1042.25
380 lb. pork					21.85	21.85
Falling market, loss						32.77
Stationary market, profit	61.03					
	1157.90	1096.87			1157.90	1096.87
Lot 5, 16 Steers.						
To 15458 lb. at \$3.60 . . .	556.49	556.49				
Feed, 140 days	404.63	404.63				
Freight, etc.	40.00	40.00				
By 20105 lb. beef			5.15	4.85	1035.41	975.09
295 lb. pork					16.96	16.96
Falling market, loss						9.07
Stationary market, profit	51.25					
	1052.37	1001.12			1052.37	1001.12
Lot 6, 16 Steers.						
To 15448 lb. at \$3.35 . . .	517.51	517.51				
Feed, 140 days	390.32	390.32				
Freight, etc.	40.00	40.00				
By 19925 lb. beef			5.10	4.85	1016.18	966.36
325 lb. pork					18.69	18.69
Falling market, profit		37.22				
Stationary market, profit	87.04					
	1034.87	985.05			1034.87	985.05

TABLE 11—Continued.

Financial statement end of 168 days, Nov. 29, 1902, to May 16, 1903.	DISBURSEMENTS.		MARKET PRICE PER CWT.		RECEIPTS.	
	Station- ary.	Falling.	Station- ary.	Falling.	Station- ary.	Falling.
Lot 1, 16 Steers.						
To 14953 lb. at \$4.75 ...	\$710.27	\$710.27				
Feed, 168 days	483.11	483.11				
Freight, etc.	40.00	40.00				
By 21765 lb. beef			\$6.75	\$5.50	\$1469.14	\$1197.08
388 lb. pork					22.31	22.31
Falling market, loss						13.99
Stationary market, profit	258.07					
	1491.45	1233.38			1491.45	1233.38
Lot 2, 16 Steers.						
To 17836 lb. at \$4.55 ...	811.54	811.54				
Feed, 168 days	583.04	583.04				
Freight, etc.	40.00	40.00				
By 24710 lb. beef			6.65	5.45	1643.22	1346.70
460 lb. pork					26.45	26.45
Falling market, loss						61.43
Stationary market, profit	235.09					
	1669.67	1434.58			1669.67	1434.58
Lot 3, 16 Steers.						
To 16305 lb. at \$4.20 ...	684.81	684.81				
Feed, 168 days	535.19	535.19				
Freight, etc.	40.00	40.00				
By 22415 lb. beef			6.35	5.15	1423.35	1154.37
435 lb. pork					25.01	25.01
Falling market, loss						80.62
Stationary market, profit	188.36					
	1448.36	1260.00			1448.36	1260.00
Lot 4, 16 Steers.						
To 16355 lb. at \$3.85 ...	629.67	629.67				
Feed, 168 days	526.95	526.95				
Freight, etc.	40.00	40.00				
By 21920 lb. beef			5.65	5.00	1238.48	1096.00
480 lb. pork					27.60	27.60
Falling market, loss						73.02
Stationary market, profit	69.46					
	1266.08	1196.62			1266.08	1196.62
Lot 5, 16 Steers.						
To 15458 lb. at \$3.60 ...	556.49	556.49				
Feed, 168 days	500.04	500.04				
Freight, etc.	40.00	40.00				
By 21245 lb. beef			5.35	4.85	1136.61	1030.38
355 lb. pork					20.41	20.41
Falling market, loss						45.74
Stationary market, profit	60.49					
	1157.02	1096.53			1157.02	1096.53
Lot 6, 16 Steers.						
To 15448 lb. at \$3.35 ...	517.51	517.51				
Feed, 168 days	479.69	479.69				
Freight, etc.	40.00	40.00				
By 20825 lb. beef			5.30	4.85	1103.73	1010.01
410 lb. pork					23.58	23.58
Falling market, loss						3.61
Stationary market, profit	90.11					
	1127.31	1037.20			1127.31	1037.20

TABLE 11—Continued.

Financial statement end of 179 days, Nov. 29, 1902, to May 28, 1903.	DISBURSEMENTS.		MARKET PRICE PER CWT.		RECEIPTS.	
	Station- ary.	Falling.	Station- ary.	Falling	Station- ary.	Falling.
Lot 1, 16 Steers.						
To 14953 lb. at \$4.75 . . .	\$710.27	\$710.27				
Feed, 179 days	520.54	520.54				
Freight, etc.	40.00	40.00				
By 22315 lb. beef			\$7.00	\$5.40	\$1562.05	\$1205.01
419 lb. pork					24.09	24.09
Falling market, loss						41.71
Stationary market, profit	315.33					
	1586.14	1270.81			1586.14	1270.81
Lot 2, 16 Steers.						
To 17836 lb. at \$4.55 . . .	811.54	811.54				
Feed, 179 days	627.34	627.34				
Freight, etc.	40.00	40.00				
By 25120 lb. beef			6.90	5.40	1733.28	1356.48
500 lb. pork					28.75	28.75
Falling market, loss						93.65
Stationary market, profit	283.15					
	1762.08	1478.88			1762.03	1478.88
Lot 3, 16 Steers.						
To 16305 lb. at \$4.20 . . .	684.81	684.81				
Feed, 179 days	575.49	575.49				
Freight, etc.	40.00	40.00				
By 23010 lb. beef			6.50	5.15	1495.65	1185.01
475 lb. pork					27.31	27.31
Falling market, loss						87.98
Stationary market, profit	222.66					
	1522.96	1300.30			1522.96	1300.30
Lot 4, 16 Steers.						
To 16355 lb. at \$3.85 . . .	629.67	629.67				
Feed, 179 days	564.53	564.53				
Freight, etc.	40.00	40.00				
By 22450 lb. beef			5.80	4.90	1302.10	1100.05
520 lb. pork					29.90	29.90
Falling market, loss						104.25
Stationary market, profit	97.80					
	1332.00	1234.20			1332.00	1234.20
Lot 5, 16 Steers.						
To 15458 lb. at \$3.60 . . .	556.49	556.49				
Feed, 179 days	537.62	537.62				
Freight, etc.	40.00	40.00				
By 21780 lb. beef			5.50	4.80	1197.90	1045.44
420 lb. pork					24.15	24.15
Falling market, loss						64.52
Stationary market, profit	87.94					
	1222.05	1134.11			1222.05	1134.11
Lot 6, 16 Steers.						
To 15448 lb. at \$3.35 . . .	517.51	517.51				
Feed, 179 days	513.24	513.24				
Freight, etc.	40.00	40.00				
By 21055 lb. beef			5.40	4.80	1136.97	1010.64
480 lb. pork					27.60	27.60
Falling market, loss						32.51
Stationary market, profit	93.82					
	1164.57	1070.75			1164.57	1070.75

TABLE 12.—SUMMARY OF TABLE 11, SHOWING PROFITS OR LOSSES AT STATED INTERVALS DURING EXPERIMENT BOTH ON STATIONARY AND FALLING MARKET.

Lot No.		Statement Jan. 24, 1903, end of 56 days.		Statement Feb. 21, 1903, end of 84 days.		Statement Mar. 21, 1903, end of 112 days.		Statement Apr. 18, 1903, end of 140 days.		Statement May 16, 1903, end of 168 days.		Statement May 28, 1903, end of 179 days.	
		Loss.	Profit.	Loss.	Profit.	Loss.	Profit.	Loss.	Profit.	Loss.	Profit.	Loss.	Profit.
1	Falling. Stationary.	51.52 10.67	..... .....	71.10	 26.22	53.21	 79.48	26.65	 145.77	13.99	 258.07	41.71	 315.33
2	Falling. Stationary.	65.79 8.35	..... .....	106.90	 46.10	96.36	 87.46	29.50	 168.34	61.43	 235.09	93.65	 283.15
3	Falling. Stationary.	91.49 56.79	..... .....	86.58 3.35	..... .....	105.73	 31.58	47.49	 121.79	80.62	 188.36	87.98	 222.66
4	Falling. Stationary.	80.65 63.43	..... .....	67.84 40.55	..... .....	75.47	 2.19	32.77	 61.03	73.02	 69.46	104.25	 97.80
5	Falling. Stationary.	84.08 51.47	..... .....	45.28 53.93	..... .....	60.07 50.81	..... .....	9.07	 51.25	45.74	 60.49	64.52	 87.94
6	Falling. Stationary.	73.90 40.81	..... .....	..... 7.81	..... .....	19.95	 7.59	..... .....	37.22 87.04	3.61	 90.11	32.51	 93.82

It will be seen in Table 12 that at no time during the course of the experiment would it have been possible to sell any of the six lots of steers profitably on the basis of a falling or the actual market except in the case of the inferior cattle. These could have been marketed profitably at the close of the third or fifth four-week periods of the experiment. Up to the end of the second period, January 24, 1903, none of the grades could have been sold profitably on either the actual market or a market identical with that of November 29, 1902, when the experiment began. February 21, three months from the opening of the experiment, the fancy and choice lots could have been sold at a profit on the basis of a stationary market. At the end of the fourth period, and thereafter, any of the lots would have sold profitably on a stationary market excepting the common grade at the close of the fourth period.

These results go to show that the early months of the feeding period are not of necessity the most profitable months as many feeders suppose. Indeed in this case the opposite was true. The fact that all of the cattle were given a partial grain ration during the four weeks preceding the test doubtless detracted from the gains which would otherwise have been shown in the first period, because the first increase in weight by steers in the average feed lot is attributed largely to "fill."

Under normal market conditions, that is, when prevailing prices of beef steers remain about stationary, the better grades of feeding cattle begin returning a profit sooner than do the lower grades, as is shown by the summary in Table 12. For example, the fancy and choice steers could have been profitably disposed of four weeks earlier than either the good, medium, common, or inferior grades, assuming a steady market throughout the experiment. Further, on April 18, the earliest date at which the statement shows a balance to the credit of all the grades, on a stationary market, the fancy, choice, and good cattle had earned an average profit relatively more than twice as great as that of the three lower grades.

That conditions were unusual and unfavorable for making it possible to show that any one of the lots was fed at a profit in the feeding experience, the results of which are detailed in this bulletin, in no way lessens the value of this experiment. The prices prevailing for feeds were normal, the unusual factor was that of the radical decline in the market. However, the data derived are independent of the particular market conditions at this time and serve as a basis for calculating profits or losses under varying market conditions.

Under the conditions prevailing at the time of this experiment, all lots were fed at a loss. The records of this experiment show definitely the extent and cause of such losses, which were occasioned by the decline in cattle values during the six months of this experiment. It will be seen that the different lots did not prove equally unprofitable. A careful study of the various factors which affect profit and loss in steer

feeding will reveal in each instance the factor or factors most concerned in bringing about these variations in losses.

Lot 6, the inferior feeders, were fed with smallest loss under this declining market. Table 13 shows that steers such as represented lot 6 declined least in the market. This indicates that less loss was occasioned by this factor here than in any other lot. This one fact would undoubtedly account for the smaller loss, but it is not the only advantage this lot possessed. Table 5 shows that these steers made the smallest relative and absolute gains in beef during feeding. Notwithstanding this fact they were in good marketable condition. Gains in live weight of steers are generally made at a loss, that is a pound of gain in beef usually costs more than it will sell for on the market, hence, that lot of steers which can be increased in value per hundred weight by putting on the least number of pounds gain, other things being equal, will have an advantage over other steers putting on greater gains, but increasing no more rapidly in value per hundred weight. There was also a very slight advantage in this lot over some of the others in the amount of pork produced.

Lot 1 stands second in its financial showing under the falling market, Table 13. Its advantage over other lots came from the fact that, as is shown in Table 5, they made by far the best gains for food consumed. That this is an all important factor will be better appreciated when it is known that in practically all other respects this lot was at a decided disadvantage. The disadvantages referred to were that they made larger gains than any other lot, hence sustained greater loss from this factor; their increase per hundred weight during fattening was the least of all lots, and they were the lightest weight at the beginning. The amount of pork produced was the smallest. The importance of securing gains in live weight economically is still further emphasized in the showing made by the steers in lot 5, which stood next to lot 1 as economical producers. A portion of what they lost in economy of production was offset by the fact that they stood second highest in increase in value per hundred weight during feeding. Only two other lots made smaller gains. These factors account for the relatively good showing of lot 5.

Lot 3 made a better financial showing than lot 2, because the increase in value per hundred weight during feeding was greater; the cost of a pound of gain was less, the gains smaller and the pork produced was greater.

The steers in lot 2 did not make as good gains for food consumed as some other lots; this was undoubtedly partially due to the fact that they were the largest framed and heaviest weight steers in the experiment. The advantage they possessed in having greater weight at the outset, which would normally amount to a considerable item in the

increase per hundred weight on original weight, was not in this instance, an important factor, as the actual increase per hundred weight during feeding was small. This lot was again at a disadvantage financially in making relatively large gains.

But little can be said for lot 4; they made a bad showing in a most unfavorable year. Their gains in beef were expensive. They apparently possessed but few of the advantages accorded either the better or the poorer grades, and were possessed of some of the disadvantages found to be present in each of them.

TABLE 13.—ACTUAL DECLINE IN MARKET VALUE PER HUNDRED WEIGHT BY MONTHS ON BASIS OF MARKET OF NOVEMBER 29, 1902, AND TOTAL DECLINE.

Lot No.	Nov. 29 to Jan. 24, 56 days.	Jan. 24 to Feb. 21, 28 days.	Feb. 21 to Mar. 21, 28 days.	Mar. 21 to Apr. 18, 28 days.	Apr. 18 to May 16, 28 days.	May 16 to May 28, 11 days.	Total, Nov. 29 to May 28, 179 days.	Actual margin per cwt. from Nov. 29 to May 28, 179 days.
1	\$0.25	\$0.30	\$0.15	\$0.15	\$0.40	\$0.35	\$1.60	\$0.65
2	.30	.45	.10	.00	.35	.30	1.50	.85
3	.20	.25	.25	.10	.40	.15	1.35	.95
4	.10	.05	.25	.05	.20	.25	.90	1.05
5	.20	*+.25	.10	.25	.20	.20	.70	1.20
6	.20	*+.25	.20	.10	.20	.15	.60	1.45

*The + sign here is used to signify that instead of a decline in the market for such steers as represented, lots 5 and 6, there was an actual advance of twenty-five cents per hundred weight during the second four weeks of the test. The market for those grades therefore was practically the same on January 24, 1903, as it was at the beginning of the experiment, November 29, 1902.

With the two exceptions noted there was a steady but somewhat irregular decline in the market for all grades from November 29 to May 28. This decline was much greater, in the better grades than in the poorer ones. This is due partly to the fact that the prices for fancy, choice, and good feeding cattle, and those prevailing for prime, choice, and good beefs were relatively high, the former because there was a great demand for feeders possessing quality, and the latter because just at the Christmas holiday season, prices for good fat cattle are apt to be relatively higher than those for the lower grades.

As the holidays passed and the season advanced, the supply of prime, choice, and good steers was so liberal that prices dropped on these grades more rapidly than on others.

In the last column will be found the actual margin of selling over purchase price for each grade. By comparing these margins with the figures in the next column to the left, it will be seen that, except in lots 4, 5, and 6, the margins of actual market transactions were not as great as the actual decline in the market. To put it in another way, under existing market conditions the market declined more rapidly than the steers increased in value during the fattening process. This is a most unusual circumstance, but one which the cattle feeder is all too frequently obliged to meet.

TABLE 14.—VALUE OF STEERS BY PERIODS ON BASIS OF STATIONARY AND FALLING MARKET.

		Lot 1.	Lot 2.	Lot 3.	Lot 4.	Lot 5.	Lot 6.	Av'rage by peri- ods for 6 lots.
Nov. 29, 1902.	Actual market value per cwt. beginning of ex- periment	\$4.75	\$4.55	\$4.20	\$3.85	\$3.60	\$3.35	.....
	Increase in market value per cwt. in 4 weeks on basis of stationary market	.25	.20	.20	.20	.25	.25	\$0.255
Dec. 27, 1903.	Market value per cwt. basis of stationary market	5.00	4.75	4.40	4.05	3.85	3.60	.....
	Actual market value per cwt. basis of existing market conditions ....	.....	.....	.....	.....	.....	.....	.....
	Increase in market value per cwt. in 4 weeks on basis of stationary market	.25	.35	.20	.20	.25	.25	.250
Jan. 24, 1903.	Market value per cwt. ba- sis of stationary market	5.25	5.10	4.60	4.25	4.10	3.85	.....
	Actual market value per cwt. basis of existing market conditions	5.00	4.80	4.40	4.15	3.90	3.65	.....
	Increase in market value per cwt. in 4 weeks on basis of stationary market	.30	.45	.50	.40	.25	.50	.400
Feb. 21, 1903.	Market value per cwt. basis of stationary market	5.55	5.55	5.10	4.65	4.35	4.35	.....
	Actual market value per cwt. basis of existing market conditions	5.00	4.80	4.65	4.50	4.40	4.40	.....
	Increase in market value per cwt. in 4 weeks on basis of stationary market	.35	.35	.35	.40	.20	.30	.325
Mar. 21, 1903.	Market value per cwt. basis of stationary market	5.90	5.90	5.45	5.05	4.55	4.65	.....
	Actual market value per cwt. basis of existing market conditions	5.20	5.05	4.75	4.65	4.50	4.50	.....
Apr. 18, 1903.	Increase in market value per cwt. in 4 weeks on basis of stationary market	.35	.40	.50	.40	.60	.45	.45

TABLE 14—Continued.

		Lot 1.	Lot 2.	Lot 3.	Lot 4.	Lot 5.	Lot 6.	Av'rage by peri- ods for 6 lots.
Apr. 18, 1903.	Market value per cwt. basis of stationary market	\$6.25	\$6.30	\$5.95	\$5.45	\$5.15	\$5.10	.....
	Actual market value per cwt. basis of existing market conditions	5.40	5.45	5.15	5.00	4.85	4.85	.....
	Increase in market value per cwt. in 4 weeks on basis of stationary market	.50	.35	.40	.20	.20	.20	\$.308
May 16, 1903.	Market value per cwt. basis of stationary market	6.75	6.65	6.35	5.65	5.35	5.30	.....
	Actual market value per cwt. on basis of exist- ing market conditions..	5.50	5.45	5.15	5.00	4.85	4.85	.....
	Increase in market value per cwt. in 11 days on basis of stationary market	.25	.25	.15	.15	.15	.10	.175
May 28, 1903.	Market value per cwt. basis of stationary market	7.00	6.90	6.50	5.80	5.50	5.40	.....
	Actual market value per cwt. on basis of exist- ing market conditions..	5.40	5.40	5.15	4.90	4.80	4.80	.....
	Actual total increase per cwt. in 179 days on basis market condi- tions Nov., 1902, to May, 1903	.65	.85	.95	1.05	1.20	1.45	.....
	Total increase per cwt. on basis of stationary market, Nov., 1902. ..	2.25	2.35	2.30	1.95	1.90	2.05	.....
	Average increase per cwt. per month on basis of stationary market	.375	.392	.383	.325	.317	.342	.356

The foregoing tabulated statement illustrates a feature of the investigation under study. Among the many difficult and important questions which the cattle feeder must decide is, at what stage of the fattening process may steers be marketed with greatest profit? How largely does the answer to this question depend upon the grade of cattle fed? And finally, do market fluctuations have a bearing upon the answer to this question? From the above table it will be seen that on a basis of a stationary market there would have been a margin between the buying

and selling price in lot 1 of \$2.25 per hundred weight; in lot 2, of \$2.35; lot 3, \$2.30; lot 4, \$1.95; lot 5, \$1.90; and lot 6, \$2.05. These margins as will subsequently be shown would have made handsome profits for the cattle feeder on all the grades. Unfortunately for the financial showing made in the actual transactions of this experiment the margins over the cost price were very small indeed. They were as follows: In lot 1, \$0.65; in lot 2, \$0.85; in lot 3, \$0.95; in lot 4, \$1.05; in lot 5, \$1.20; and in lot 6, \$1.45 per hundred weight.

The margins recorded in the table as estimated on the basis of a stationary market are somewhat unusual in that the margins for the better grades are rather too large as compared with those of the lower grades. It is true that the actual margins computed on the basis of prevailing market conditions are much more unusual. The variations in margins from the normal as based upon a stationary market are too slight, however, to render a comparison of margins between the grades impracticable; in fact, there is much of value that can be learned from such comparison. While it is true that by using the Christmas holiday market as the basis for values of beef cattle on stationary market the estimated values of prime steers as compared with medium and common grades of beef cattle are relatively high, it is equally true that the estimated value of fancy, choice, and good feeding cattle was correspondingly high at this season in 1902. The average increase per hundred weight a month on the basis of a stationary market for the three best grades, lots 1, 2, and 3, was slightly more than 38 cents. The average increase per hundred weight a month on a basis of actual market conditions in the three best grades was but little more than 13 cents.

Two factors contributed to make the margins exhibited in lots 4, 5, and 6 characteristic. First, the market did not decline either as much or as rapidly as in the better grades, and second, these grades increased in value per hundred weight rather more rapidly than is common. Much therefore is to be gained by making a careful study of the financial statement concerning lots 4, 5, and 6.

In general, it may be said that where two-year-old steers are gaining at the rate of two and one-half pounds per steer a day on rations calculated to produce that finish demanded in the market, and that in a reasonably short time with feeds at average prices, they will increase in market value at the rate of from \$0.20 to \$0.30 per hundred weight a month, providing of course the market does not decline in the meantime.

Another point that should be noted in this table is that at the beginning of the experiment the market value of the various lots was such that lot 1 was \$0.20 per hundred weight more valuable than lot 2. Lot 2 was \$0.25 per hundred weight more valuable than lot 3; lot 3, \$0.35 per hundred weight more valuable than lot 4; lot 4, \$0.25 per hundred weight more valuable than lot 5; lot 5, \$0.25 more valuable per hundred

weight than lot 6; lot 1 was \$1.40 more valuable per hundred weight than lot 6.

At the end of the experiment these differences were much less marked; lots 1 and 2 were sold on the market at the same price. They were considered only \$0.25 per hundred weight more valuable for slaughter than lot 3, and lot 3 \$0.25 per hundred weight more valuable than lot 4. Lots 5 and 6 were considered of equal value for killing purposes and but \$0.10 per hundred weight less valuable than lot 4. When marketed lot 1 was considered only \$0.60 per hundred weight more valuable than lot 6.

As bearing on the financial aspect of this experiment and cattle feeding in general it may be said that market values are bound to vary considerably from those obtained during this experiment. Cost of gains under favorable conditions need not be materially different from those in this experiment. It is interesting to note that for the feeder to have come out even and neither to have made nor lost by the feeding of the various grades in this experiment it would have been necessary to have secured margins as follows: Lot 1, \$0.93; lot 2, \$1.13; lot 3, \$1.48; lot 4, \$1.63; lot 5, \$1.59; and lot 6, \$1.63. This illustrates a fact which every cattle feeder should understand, viz., that the lower the price at which feeding cattle are purchased, no matter whether this low price is chiefly due to a prevailing dull and low market or to the fact of the cattle being poor in grade, the larger the margin must be to secure protection against loss.

The accompanying table illustrates the relative gains of about half of the individual steers in the different lots. On January 19, just fifty days after the experiment began, a metal ear label was inserted in the left ear of each steer in lot 6; on the following day, January 20, ear labels were inserted in the ears of lots 4 and 5; on January 21 in lots 2 and 3; and on January 22 in lot 1. The weight of each steer was taken just before the label was inserted. It was the intention to weigh each steer at the end of the experiment and thus determine the individual gains of each one in each lot.* This was found to be impracticable as many of the labels were soon lost and the placing of duplicates would have been a constant annoying and disturbing factor to be reckoned with in any results which final records might show. It was thought advisable, therefore, not to attempt to secure a complete record of individual gains but simply of those steers that had fortunately retained their ear labels to the last. This question of individual gains was not a part of the experiment as planned and the absence of these records does not in any way affect data which will be used to determine the object of this experiment. The incomplete record

*Experience at this Station goes to show that the metal ear label is much less liable to tear out when placed on the upper edge than on the lower edge, as recommended.

TABLE 15.—INDIVIDUAL WEIGHTS AND GAINS OF STEERS.

Lot No.	No. of steer.	Weight of steer, Jan. 22.	Wt. of steer, Champaign, May 27.	Gain in 125 days.	Average daily gain.
1	101	885	1315	430	3.44
1	102	905	1315	410	3.28
1	103	1020	1285	265	2.12
1	104	1065	1455	390	3.12
1	107	1120	1600	480	3.84
1	108	965	1250	285	2.28
1	111	990	1315	325	2.60
1	112	1050	1445	395	3.16
1	113	1045	1425	380	3.04
		Jan. 21		126 days	
2	119	1245	1675	430	3.41
2	121	1265	1580	315	2.50
2	122	1135	1465	330	2.61
2	123	1295	1670	375	2.97
2	126	1185	1400	215	1.70
3	135	985	1295	310	2.46
3	137	1120	1380	260	2.06
3	138	1010	1440	430	3.41
3	140	1350	1730	380	3.01
3	147	975	1410	435	3.45
3	148	1030	1440	410	3.25
		Jan. 20		127 days	
4	151	1140	1250	110	.866
4	153	1025	1385	360	2.83
4	157	1085	1375	290	2.28
4	158	1130	1455	325	2.55
4	159	1250	1540	290	2.28
4	163	1125	1465	340	2.67
4	164	1075	1375	300	2.36
5	165	950	1300	350	2.75
5	166	1030	1350	320	2.51
5	168	1135	1500	365	2.87
5	169	1070	1460	390	3.07
5	171	1005	1285	280	2.20
5	172	1070	1340	270	2.12
5	173	985	1300	315	2.48
5	175	1030	1300	270	2.12
5	176	990	1375	385	3.03
5	178	895	1210	315	2.48
5	179	985	1400	415	3.26
5	180	1130	1475	345	2.71
		Jan. 19		128 days	
6	181	1060	1370	310	2.42
6	182	1045	1390	345	2.69
6	183	925	1225	300	2.34
6	184	1180	1395	215	1.67
6	185	925	1215	290	2.26
6	186	1000	1315	315	2.46
6	188	955	1290	335	2.61
6	189	1020	1425	405	3.16
6	190	1160	1445	285	2.22
6	192	965	1295	330	2.57
6	193	1055	1305	250	1.95
6	195	1110	1190	80	.625
6	196	925	1175	250	1.95

illustrates a point or two worthy of notice; first, that as far as these records go, the steer that made the greatest average daily gain was steer No. 107 in lot 1, while the steer making the lowest average daily gain was No. 195 in lot 6. The former gained at the rate of 3.840 pounds a day, while the latter gained only .625 of a pound per day. This difference is extreme and must be looked upon as an individual rather than a grade characteristic. Careful study of the above table reveals the fact that the steers in the better grades were not only more rapid gainers, but also much more uniform in their daily gains than the steers in the lower grades. The steers with high average daily gains in lot 1 were the rule while the steers with such averages in lot 6 were very unusual indeed. The individual gains in the other lots indicate that the better bred the steer the more uniform and consistent his gains.

Steer No. 107 in lot 1 gaining nearly four pounds per day for four months, and that under carload feed lot conditions on a steer well fleshed as a feeder, but shows the opportunity and illustrates the possibilities in store for the systematic, painstaking breeder of beef cattle who will continue to select his animals to improve them in this rapid gaining, early maturing quality. Perhaps no other characteristic of beef cattle has received greater attention at the hands of breeders than this one. The fact that this one steer practically stands in a class by himself indicates that there is still opportunity for further improvement along this line. This opportunity should be made the most of by breeders of beef cattle until it can no longer be said that beef production can only be engaged in by well-to-do farmers since returns are slow and capital is too long tied up without cash returns.

It would indeed be interesting to know the relative cost of beef on these two steers to which reference has been made, namely No. 107 in lot 1 and No. 195 in lot 6. This of course could not be determined in this test without seriously interfering with the car-lot conditions believed to be so essential as a practical feature of this experiment. In general it is clear that the steer making the greatest gains consumed the most feed. He was always one of the first at the trough as soon as the feed was distributed and among the last to leave it; when he did, he seemed satisfied and contented. He had a proud, stately carriage that would become individuals of any species of the animal kingdom. On the contrary, the slow gaining steer was dainty and delicate about his eating and seldom showed signs of having enjoyed or made good use of his meal. He had that dull "hang-dog" look that always accompanies slight grudging, and inefficient expenditure of energy.

These evidences of better gaining capacity seemed to stand out more clearly during the feeding process or after a closer acquaintance secured by actual every day contact with the steers than in the yards as feeders. This suggests the importance of the great advantage of breeding the

feeders which one finishes. A system of beef production that involves the breeding and finishing of the steers by the same individual gives opportunity to discard the feeders which do not promise well before too much expensive feed has been wasted in trying to finish them for the market.

CONCLUSIONS.

1. More rapid and much larger gains may be secured on the better than on the more common grades.

2. The results of this experiment clearly show that when the various grades of beef cattle are put in the best marketable condition there is a very definite relation between the percentages of dressed beef and the grade of cattle involved. The better the grade of cattle the higher the percentages of dressed beef.

3. Low grade cattle carry larger percentages of internal fat than the better bred ones, while there appears to be a more abundant and more evenly distributed layer of surface fat on the better bred steers.

4. As the differences between feeders tend to disappear as the feeding process goes on, the differences in quality between the various grades of feeding cattle are more pronounced than such differences between the various grades of beef or fat cattle. Quality is the more important in feeding cattle; condition in fat cattle.

5. Primarily this experiment was outlined to determine the relation between the grade of feeding steers and their "feeding qualities"; that is, whether the quality of a feeder determines his capacity for making gains, his ability to use feed economically, and the nature of the gains made. However, both the market and slaughter tests of the various grades as finished clearly indicate that to the packer and butcher condition is of first importance.

6. The grade of cattle the finishing of which will return to the cattle feeder the greatest profit will depend upon the following considerations:

(a) The relative ability of the various grades to use feed for the production of gain and finish as shown by the data in this bulletin. See Table 7.

(b) The relative cost of the various grades of feeding cattle.

(c) Cost of feed.

(d) The method of feeding and time of marketing.

(e) The range in prices between prime and common rough steers or between the highest and lowest grades of beef cattle.

7. The greater the cost of the feed used, the greater is the advantage in favor of the better grades, both because under normal market conditions, in these grades the gains and finish are put on with less relative feed consumption than in the lower ones, although this difference is less marked in the inferior than in the intermediate grades

and because the cost of feed is a larger factor in the feeding of the lower than the higher grades.

8. The greater the spread in the market between the various grades of feeders, the more is the advantage in favor of the commoner grades. As a rule the price of common rough steers fluctuates less than the price for prime steers and the price of the inferior and common grades of feeders varies less than those of the choice and fancy grades.

9. A concentrated ration and shorter feeding period tend to favor the feeding of the lower grades, that is, a ration with a wide nutritive ratio like corn and timothy hay or straw without the addition of a nitrogenous concentrate or roughage and where the concentrate comprises a large percentage of the ration would favor cattle of the lower grades because they are older and the process of finishing is largely a process of fattening.

Again prices for the lower grades of fat or beef cattle are more or less affected by range and holiday competition and are usually relatively low at such seasons.

10. Older cattle of the more common grades can undoubtedly be put in marketable condition on a shorter full feed period than can younger cattle of the same weight which would grade higher, because the older the cattle the less the increase in weight required to finish them.

11. The greater the spread in the market between the various grades of fat steers the more is the advantage in favor of the better grades.

12. Opportunities for larger profits, and losses as well, lie with the better grades of feeders.

13. Steers containing high percentages of beef blood possess greater capacity for consuming large quantities of feed than steers of a more common grade, especially in the later weeks.

14. Age and condition as well as quality are important factors to be reckoned with in the management of the various grades of feeding cattle. Speaking generally of the offerings of feeding cattle at any of our leading markets it is safe to say that the better the quality and condition the younger the cattle. In securing 900 to 1,000 pound feeding cattle of the more common grades one is bound to get cattle of advanced age, say three years old at least. Choice and fancy feeders of these weights can be secured in short two-year-old cattle.

15. Steers of all grades may be finished or put in good marketable condition without carrying them to a point of fatness which necessitates small gains for food consumed.

16. The margins necessary to protect against loss in finishing the various grades of feeders are dependent upon:

- (a) The grade and cost of the cattle.
- (b) The price of feeds.
- (c) The initial weight of the cattle.
- (d) The length of the feeding period.

17. The lower the price at which feeding cattle are purchased, whether because of prevailing low prices for feeders or because of the low grade of the cattle, the larger must be the margin between the buying and selling price in order to secure protection against loss.

18. The greater the cost of the feed necessary for finishing feeders, the larger must be the margin.

19. Feeding cattle of heavy weights can be finished profitably on a narrower margin than can light weight feeders.

20. Feeding cattle which require an extended feeding period for finishing require a larger margin than do feeders which can be matured in a shorter time.

GENERAL OBSERVATIONS.

Beef production on an extensive scale is an enterprise in which the uninformed and inexperienced can not afford to engage. For several years it has been developing into a more complex and difficult, and therefore a more hazardous business. Conditions as to market price of feeding and fat cattle and cost of feeds have never been identical during any two consecutive years and seldom more than similar at irregular intervals. Thus the man who masters the science and art of beef production in such a way as to make it profitable is a master indeed.

It is reasonable to assume that the problems confronting the men who market a large part of the fat cattle of America are the problems that should engage the attention of the investigator. It is estimated that 85 percent of the native beef cattle marketed in Chicago have been previously bought as feeders and finished by cattle feeders who do not raise the cattle they feed. In most respects the improvement in beef cattle has been along lines calculated to render them more valuable and profitable to cattle raisers who breed and develop the cattle they finish for the block, rather than to render them especially fitted for the enterprise engaged in by so many of our cattle men, namely, that of buying in the market or on the range, feeders that have been grown and developed to the point of finishing. To be more specific it may be said that the improvement in beef cattle has been along the lines of earlier maturity, refinement of form, and reduction of the percentage of bone and other products of the steer less valuable than beef. Thus it may appear on first thought that breeders have lost sight of their greatest opportunity by not rendering their cattle pre-eminently the cattle for the feed lot no matter what the varying conditions affecting this enterprise may happen to be. More careful consideration of the subject, however, will surely convince the student of beef production that all these years of improvement in beef cattle have not been in vain, for some one must breed and rear the calves that will eventually find their way to the feed lot and subsequently to market. All conditions indicate that ultimately

more of the steers fed in the corn belt will be reared there. Evidence of the superiority of the well bred steer for this purpose is too manifest to require discussion at this time.

Notwithstanding the fact that breeders have improved the early maturing quality of beef cattle to a greater extent than any other, the wide variations in the gains of individual steers within the grades of feeding cattle used in this experiment point strongly to the possibility of still further improvement along this line. Breeders of beef cattle should not be slow to take advantage of this opportunity.

Incidentally the results of this experiment show which of the six grades of feeding cattle was fed with the least loss under conditions which have prevailed during the winter of 1902-'03, and the data will also afford a basis for computing probable profits under varying market conditions. Experienced feeders believe that the largest factors in determining the relative profits in feeding the different grades of cattle are local and market conditions. It is obvious that cattle feeders can not control the markets for their cattle; they should understand fully, however, the bearing which market conditions have upon the question of what grade of feeding cattle is likely to return to the feeder the greatest profits in any given year. The big questions are, of course, the relative rapidity, extent, nature, and cost of gains with the various grades.

When prices rule low in the beef cattle class and the market is dull and has a downward tendency, the range of prices between prime steers and common rough steers is narrow, and as a result, condition or fat is more important than quality or beef blood. As a rule, prices of common rough steers in the beef cattle class fluctuate less than the prices for prime steers. Hence, it will be seen that in general there is less liability to large losses from market fluctuations in the feeding of the commoner than the better grades of feeding cattle. On the other hand the chances for making large profits are undoubtedly greatest with the better grades. As a feeding proposition there is perhaps a larger element of speculation involved in the handling of the well-bred than the common-bred steer. It is best for the beginner to handle a few loads of the commoner kinds, as the chances for heavy losses are thereby reduced to the minimum, and the capital involved is not large. It is well, however, to bear in mind that cattle of common and inferior grades must be purchased at a low price or what has been said will not be true, for under ordinary conditions the margin for profit in feeding low grade cattle is slight.

By reducing the corn fed to meal and mixing same with roughage the importance of pork production as a factor in cattle feeding is minimized. Notwithstanding this, the pig, even under such conditions, should not be eliminated. Properly managed he may return a credit to each steer fed of approximately \$2.00.

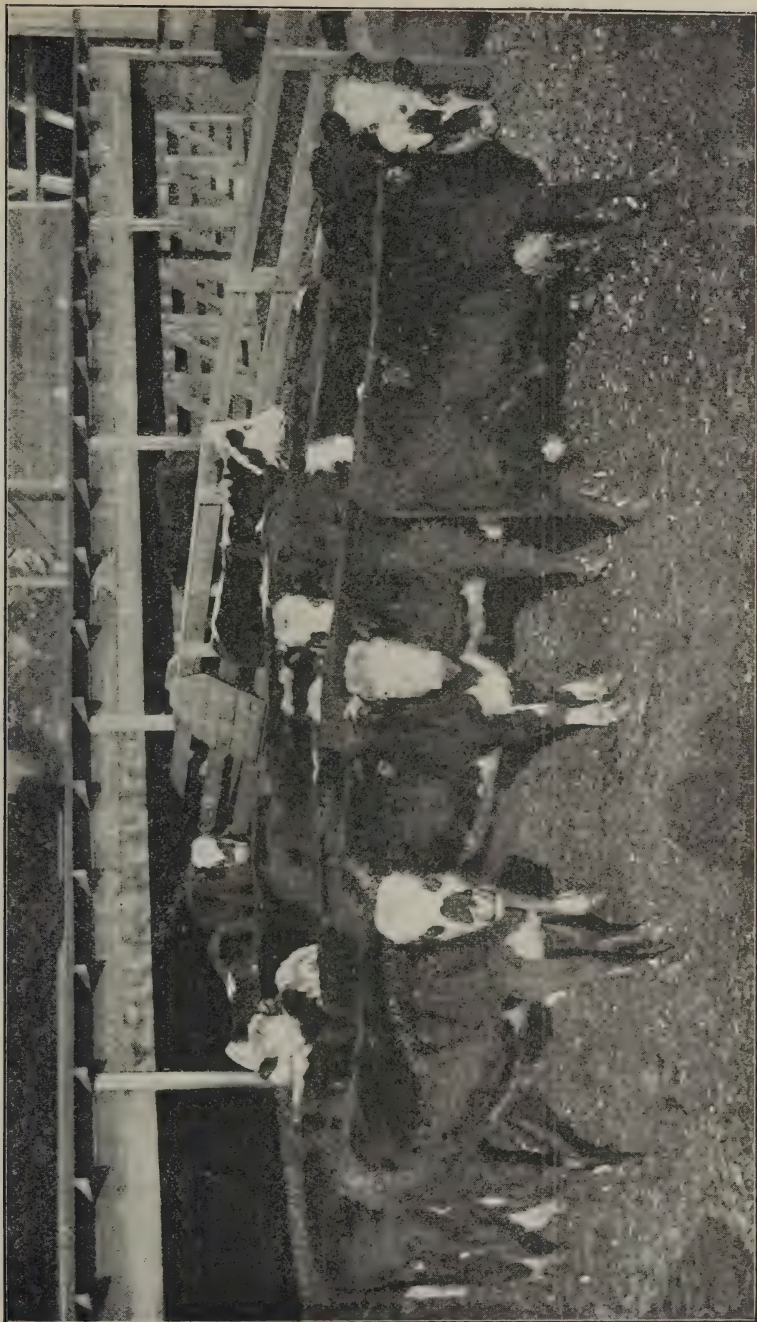


PLATE 1, LOT 1, FANCY SELECTED FEEDERS.



PLATE 2, LOT 1, AS MARKETING.



PLATE 3, LOT 2, CHOICE FEEDERS.



PLATE 4, LOT 2, AS MARKED.

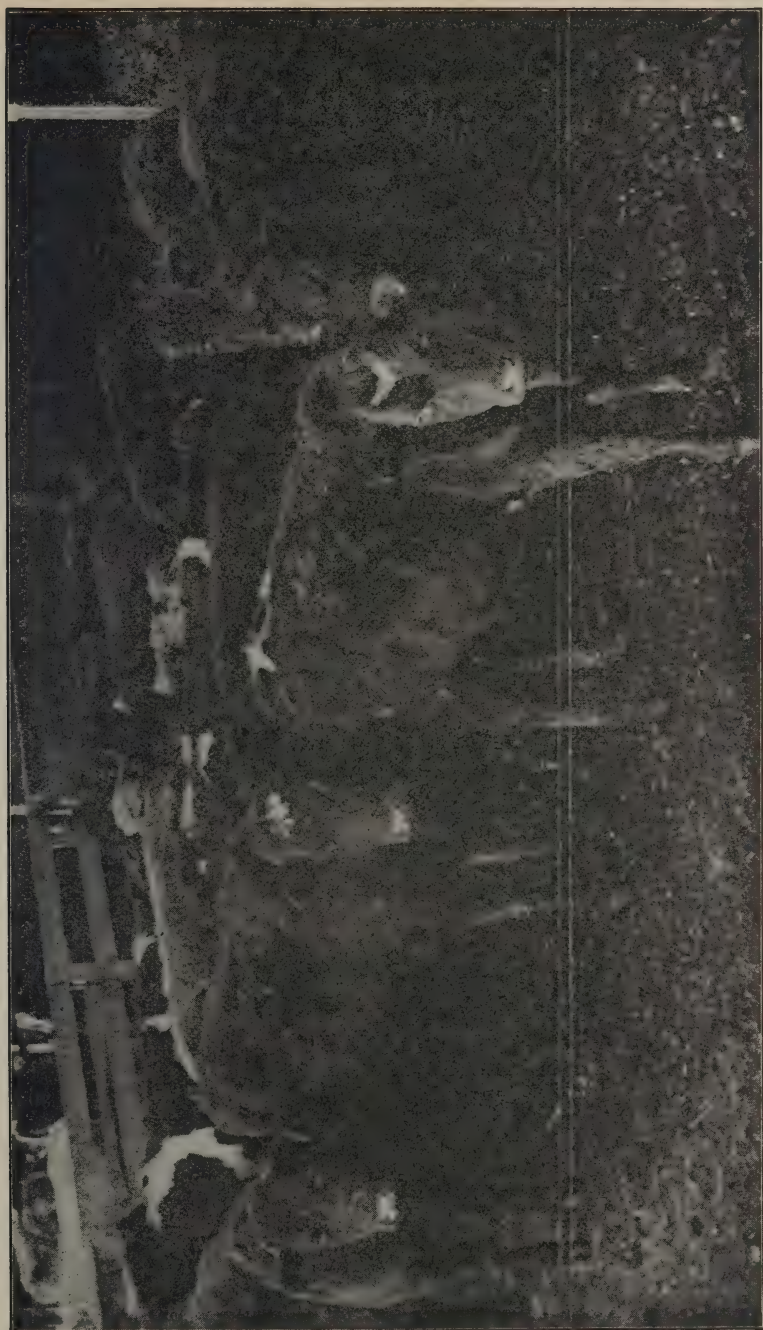


PLATE 5, LOT 3, GOOD FEEDERS.



PLATE 6, LOT 3, AS MARKED.



PLATE 7, LOT 4, MEDIUM FEEDERS.



PLATE 8, LOT 4, AS MARKETING.



PLATE 9, LOT 5, COMMON FEEDERS.



PLATE 10, LOT 5, AS MARKED.



PLATE 11, LOT 6, INFERIOR FEEDERS.



PLATE 12, LOT 6, AS MARKED.

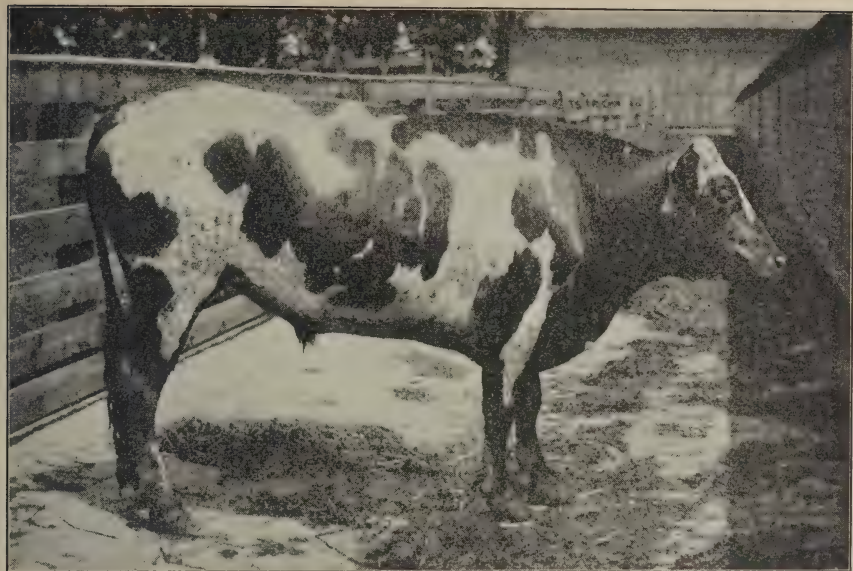


PLATE 13. THE INFERIOR FEEDER THAT GAINED BUT 80 POUNDS IN FOUR MONTHS, AS MARKETING.

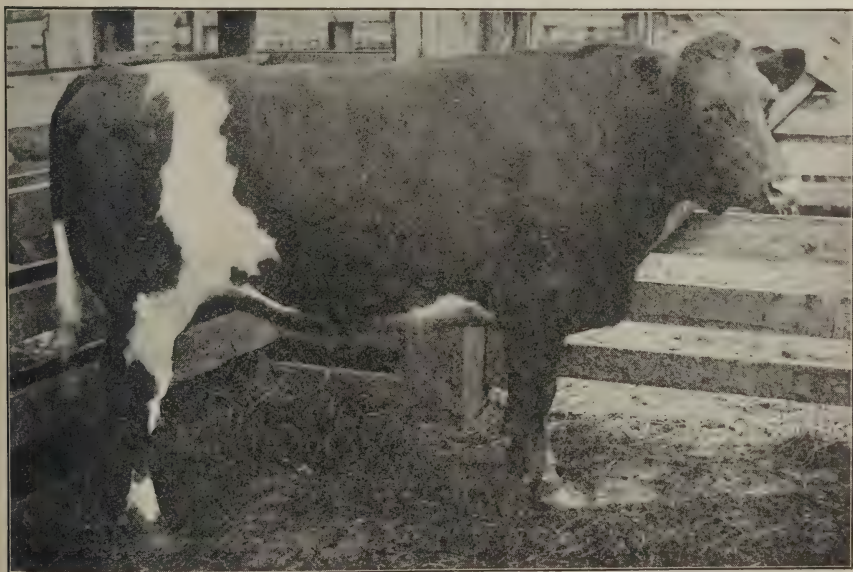


PLATE 14. THE FANCY SELECTED FEEDER THAT GAINED NEARLY FOUR POUNDS A DAY FOR FOUR MONTHS. PHOTOGRAPH TAKEN A FEW DAYS BEFORE MARKETING.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

BULLETIN NO. 91.

PREVENTING CONTAMINATION OF MILK.

By WILBER J. FRASER.



URBANA, ILLINOIS, DECEMBER, 1903.

SUMMARY OF BULLETIN NO. 91.

INTRODUCTION.—Investigation has shown that all of the troublesome changes that take place in milk and make it such a difficult product to handle properly are caused by bacteria. Page 221.

BACTERIA.—Bacteria are single-celled plants, so minute that several hundred of them placed closely side by side would equal only the thickness of ordinary writing paper. Page 221.

SOURCES OF BACTERIA IN MILK.—Bacteria exist in immense numbers in the air, and in dust and dirt of every description, and for this reason it is difficult indeed to secure milk free from germs. Page 222.

THE EFFECT OF BACTERIA ON MILK.—Bacteria not only cause milk to sour in a short time, but they make it less wholesome, and often impart a bad flavor. Page 223.

OBJECT OF THE INVESTIGATION.—The purpose of the investigation reported in this Bulletin was to determine the effect of the different common operations performed each day in dairies and dairy barns upon the bacterial content of milk, and to find the most practical methods by which this contamination could be reduced to the least possible amount. Page 224.

METHOD USED.—Petri dishes filled with a sterile nutrient medium were exposed for a definite length of time, and then held at a warm temperature for three days, when the colonies were counted. The basis taken was the number of colonies developed on 63 square centimeters of surface from a half-minute exposure. Page 224.

CHECKS ON THE WORK.—To learn whether petri dishes might become contaminated before or after direct exposure, dishes were left in dusty places in the barn, but not exposed. In the thirty-nine dishes thus treated, but seven colonies developed. Page 227.

BACTERIAL CONDITION OF OUTDOOR AIR.—Of the exposures made in the open field, fifty percent were sterile, while of those made in the barnyard, twelve percent were sterile. Page 228.

BACTERIAL CONDITION OF AIR IN DAIRY BARN.—The results obtained in these barns show that with a dry and dusty floor the bacterial content of the air is large when the cows are in the barn, even though they are not brushed and no hay or bedding is moved. With an efficient system of ventilation and a clean cement floor, the number of bacteria in the air is decreased greatly. Dust arising from brushing cows is more heavily laden with bacteria than dust from most other sources. Page 229.

EXPERIMENTAL MILKING ROOM.—The dust which arises from brushing cows, although heavily laden with bacteria, soon settles when the room remains closed, and in half an hour the air is practically free from bacteria. Page 235.

BOTTLING ROOM.—Everything in this room is kept clean, and the floor is usually damp. Eighty percent of the exposures made there were sterile. Page 236.

WASHING UDDERS BEFORE MILKING.—The number of colonies developed from exposures under apparently clean unwashed udders was three times as many as under the same udders after washing. With soiled or muddy udders, such as are frequently found in dairies, the benefits derived from washing udders are much greater than these results show. Page 237.

WEIGHT OF DIRT WHICH FALLS INTO MILK DURING MILKING.—With udders that were apparently clean it was found that an average of $3\frac{1}{2}$ times as much dirt fell from the unwashed udders as from the same udders after they were washed. With soiled udders the average was 18, and with muddy udders 90 times as much dirt from the unwashed as from the washed. Page 243.

CONCLUSIONS.—The results of the work described in this Bulletin are of vital importance to the practical dairyman, as they show that extreme cleanliness is absolutely essential to the most successful dairying. Page 245.

PREVENTING CONTAMINATION OF MILK.

BY WILBER J. FRASER, CHIEF IN DAIRY HUSBANDRY.

INTRODUCTION.

It has long been known that extreme cleanliness is absolutely essential to the most successful dairying, but the real reason for this was not known until within the last few decades. Investigations of recent years have shown that all of the troublesome changes that take place in milk and make it such a difficult product to handle properly are caused by bacteria. In fact, successful dairying depends largely upon the ability to limit the number of bacteria obtaining access to milk, and to control those that cannot be kept out.

Milk becomes contaminated in so many ways in the process of milking that it is extremely difficult to secure it free from germs, but this has been done in an experimental way a sufficient number of times to prove that milk as formed in the milk glands of a healthy cow is germ free. Since bacteria invade the udder to some extent, and develop there, milk as drawn from the udder is not entirely free from germs; this is especially true of the first milk drawn.

When milk is secured free from germs, the common phenomenon of souring does not take place, but it remains sweet and practically unchanged indefinitely. It is, therefore, of the utmost importance not only to the milk producer and the consumer, but to the butter and cheese maker as well, that this ideal condition be as nearly reached as possible. By observing a few precautions dairymen can prevent the contamination of milk to a large extent, and thus produce, at but slight trouble or expense, a much better and more valuable as well as a longer keeping product.

BACTERIA.

Comparatively little was known of bacteria until within the last two decades, but during this time much attention has been given to the study of these microscopic plants, and the knowledge of them has made wonderful progress. The study had not advanced far when it was discovered that certain species of bacteria had the power to produce disease, and the reputation which they thus gained clings to all bacteria in the popular mind to-day. With many people the words "bacteria" and "disease" are nearly synonymous terms, although the power to produce disease belongs to a small percentage only of the numerous species of these organisms. Bacteria are the chief agents in decay, and without decay all organic matter would remain unchanged after death.

SIZE.

These organisms, which are of such great importance, are so extremely minute that it is difficult to gain an adequate conception of their size. If they could be placed closely side by side, it would take several hundred to equal the thickness of ordinary writing paper. Of course, they can be seen only with the most powerful microscope. If bacteria could be magnified to the size of base-balls, a man enlarged in the same proportion would be over fifty miles high.

FORM.

In the more complex species of plants and animals, each has a form peculiar to itself. In bacteria, which are single-celled plants, there can be little difference in the form of the different species because of their simple structure and minute size. Although there are hundreds of species of bacteria, they all come under three different forms, which may be represented by balls, rods, and corkscrews.

[SOURCES OF BACTERIA IN MILK.

Since milk, as formed in the milk glands of a healthy cow, is germ free, we would not expect to find bacteria always present in it, at least in such large numbers as usually exist. Freshly drawn milk may contain from 200 to 100,000 bacteria per c. c., or from 800 to 400,000 per teaspoonful, according to the care with which it is handled. By the time milking is completed, under ordinary conditions, the milk is badly contaminated indeed. It is then of the greatest importance to the dairy interests to learn the sources of bacteria which gain access to milk. The number found in freshly drawn milk is a good indication of the sanitary conditions under which it was produced.

Let us pause for a moment and see where these bacteria are in nature, and how they so readily gain access to milk. Investigation has shown that their presence is well-nigh universal. They are found floating on the dust in the air, and in the soil and water. It is difficult to find a cubic yard of air that does not contain thousands of them, and soil and water contain them in vastly larger numbers. In the air of enclosed spaces, as in dwellings and barns, they are much more numerous than out of doors. In the air of barns they are generally abundant, especially if a dust has been raised. They are also found in immense numbers in dung and dirt of every description, on the cows' udders, the hands of the milkers, and not only in the seams and cracks of unsterilized dairy utensils, but also clinging to the entire surface. Wherever there is a lodging place for dust, there bacteria will be found in vast numbers. The least stir in the bedding or of the dust on the floor will send myriads of them floating into the air. Everywhere in nature, then, these organ-

isms exist with the power to multiply with astonishing rapidity unless held in check by the conditions surrounding them. In most places they are dormant or growing very slowly. The bacteria clinging to the hair and dirt on a cow and those riding on the dust in the air, multiply slowly, if at all, but they have the power of growth, and as soon as they find moisture and nourishment, they develop rapidly if the temperature is favorable.

Freshly drawn milk is especially adapted to the growth of nearly all species of bacteria, as it contains all the elements necessary for their development, and besides affords a favorable temperature. Those that gain access to it, therefore not only contaminate it themselves, but multiply at an astonishing rate if the milk is not immediately cooled to near the freezing-point. The increase of bacteria usually occurs by the simple division of one individual into two. The exceptional power of rapid multiplication is one of their most important properties, especially in relation to dairying. In some species one germ may become two, under favorable conditions, in half an hour. Such multiplication in a geometrical ratio results in an increase of numbers with almost inconceivable rapidity. At this rate, starting with 1 organism, in half an hour there would be 2; in one hour each of these would have again divided, making 4; in one and a half hours 8, in two hours 16, in three hours 64, in four hours 256, etc., and if this rate of multiplication could be maintained for twenty-four hours there would be some 17,000,000, all the offspring of a single bacterium within a single day. Fortunately for humanity this maximum multiplication rarely occurs, as various factors soon interpose to check the development of these germs.

Temperature, moisture, and food supply are the conditions controlling the multiplication of bacteria. Milk at all temperatures furnishes ideal conditions as to moisture and food, and when freshly drawn its temperature is ideal for most species. This being the case, all germs that gain access to milk may multiply rapidly unless checked by an artificially low temperature or by the addition of some substance that prevents growth.

The temperature at which bacteria multiply most rapidly varies with the species. Some grow best at 75° F., and others at 90°, while a few reach their maximum rate of development at still higher temperatures.

THE EFFECT OF BACTERIA ON MILK.

The cow is a much more economical producer of human food than is the steer or the pig, and if bacteria could be prevented from getting into milk, dairying would be a far more remunerative occupation than it now is.

In milk, for whatever purpose it is to be used, nearly all species of bacteria are detrimental. They not only cause it to sour in a short time,

but make it less wholesome for infants and invalids, as well as often impart a bad flavor. Certain species, however, are essential in the manufacture of good butter and cheese.

The changes which bacteria produce in milk are several; the most common, and also the most important one, being the conversion of milk sugar into lactic acid, which is known as souring. Owing to the rapid changes which bacteria cause in milk, it is not, as ordinarily handled, in suitable condition for human food for longer than twelve to forty-eight hours after it is drawn, the time depending upon the temperature at which it is held. It is, then, essential that every family receive daily a fresh supply of milk. This necessitates the expenditure of a large amount of time and labor in delivering the milk. Generally speaking, it costs as much to deliver milk to the consumer after it is produced as it does to produce it. From this it is seen that were it not for the action of bacteria, a large supply of milk could be delivered at one time, and thus reduce the delivery to once a week, or even less frequently, which would increase the producer's profit several fold or greatly reduce the price to the consumer.

When we consider that milk is used daily by all classes of people, it will be seen that the action of bacteria on milk is of the utmost importance from a financial standpoint alone. In connection with this, the health of the community should be considered, for disease germs frequently find their way into milk where slovenly methods are practiced, and thus endanger not only the health but even the lives of the consumers.

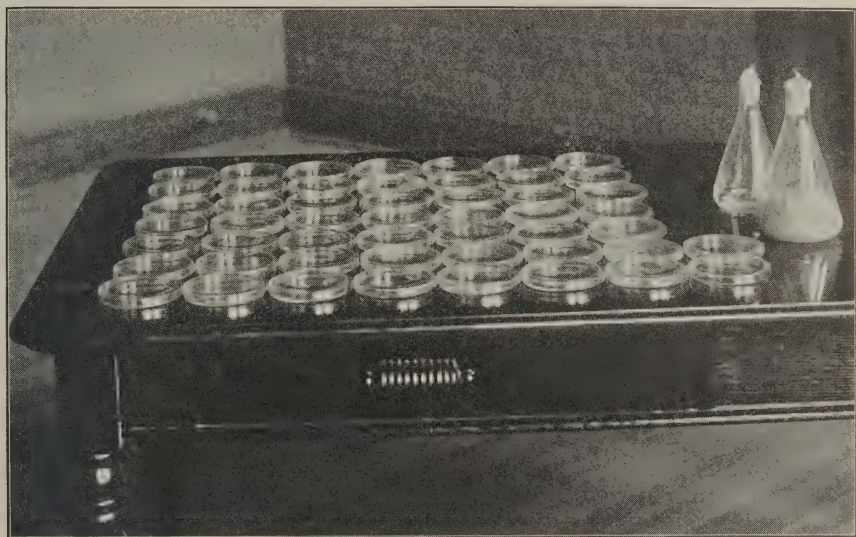
OBJECT OF THE INVESTIGATION.

The purpose of the investigation reported in this bulletin was to determine the effect of the different common operations performed each day in dairies and dairy barns upon the bacterial content of milk, and to find the most practical methods by which this contamination could be reduced to the least possible amount.

METHOD USED.

In this investigation nearly all of the results were obtained by exposing petri dishes, which are circular glass dishes with vertical sides having covers similar in shape only large enough to fit easily over the sides, as shown in cut No. 1. The dishes used for this work were one-half inch deep and three and a half inches in diameter, the bottom containing sixty-three square centimeters of surface. These dishes were washed, and sterilized by baking in an oven at a temperature of 140° C. or 284° F. for twenty minutes. Enough sterilized beef broth containing three-fourths of one percent agar was then poured into them to cover the bottoms of the dishes about one-eighth inch deep. The beef broth furnished the nutrient material for the growth of the bacteria, and the

agar caused it to solidify when cool, so that it would not run when the dishes were tilted. These sterilized dishes were filled with the sterile nutrient medium in a laboratory where the air was comparatively free from bacteria, so that the least possible contamination would take place during filling. The dishes were then held at a warm temperature for two days, so that if any were contaminated they could be easily detected, for in that time the bacteria would have developed into colonies large enough to be visible, and, of course, all dishes not sterile were rejected.



CUT 1.—PETRI DISHES FILLED WITH NUTRIENT MEDIUM, READY TO BE EXPOSED.

These sterile dishes were kept closed and carried to the place of exposure in a carrying case made for the purpose. An exposure was made, as shown in cuts 2 and 3, by placing a petri dish in a horizontal position, removing the cover for a definite length of time, then quickly replacing it. After being exposed, the dishes were returned to the laboratory, where they were held at a warm temperature for three days. Wherever a colony developed it showed that the dish had become contaminated by one or more bacteria falling on the nutrient medium in the dish at the time of exposure, and by counting these colonies the number of places that bacteria had fallen on the medium was determined.

That an accurate record of all exposures might be kept, the dishes were numbered consecutively as exposed, and the date, place, condition of exposure, and length of time exposed were recorded.

In this work the basis taken was the number of colonies developed on sixty-three square centimeters of surface for a half-minute exposure. In some places the exposures were necessarily for a shorter time, or the colonies

would have been entirely too numerous to count. For example, under udders the exposures were usually for only five seconds, and the actual number counted in each case was multiplied by six to bring it to the basis of an exposure of thirty seconds.

In this investigation 1,185 petri dishes were exposed. As the tables giving a complete record of these exposures are too extensive for publication, and of little general interest, they were condensed by dividing the exposures into groups as far as possible and the average for each



CUT 2.—EXPOSING PETRI DISH IN HANDS UNDER UDDER DURING MILKING.

group is given. Averages were computed only when several exposures were made at the same time and under similar conditions.

The first column of each table contains the laboratory number of the dish, or the first number of a group of dishes exposed at the same time and place, and the second column gives the date of exposure. The first column at the right gives the number of exposures averaged, and the remaining column or columns the actual or average number of colonies developed.

CHECKS ON THE WORK.

As a further check against error and to learn whether petri dishes might become contaminated before or after direct exposure, certain tests were made.

January 21, four dishes were carried in the barn for five minutes at a brisk walk without removing the cover. Only one developed a colony, and that but a single one. On the same day one dish stood for



CUT 3.—PETRI DISH CLOSED JUST AFTER BEING EXPOSED UNDER UDDER.

twenty-five minutes in the barn and another was moved rapidly for five minutes through the dust arising from a pile of fodder freely agitated with a fork. Both covers were left closed, and neither developed a colony.

Again, twenty-eight dishes stood covered for five days in the dairy building, and twenty-three or eighty-two percent remained sterile.

March 10, five dishes still in the carrying case stood for one hour in the barn. These same dishes had been standing for five days in the dairy building. Only one dish developed a single colony. From all of which it is concluded that petri dishes are not subject to contamination even when in motion in a dusty barn except while the cover is removed.

TABLE 1.—BACTERIAL CONDITION OF OUTDOOR AIR.

Laboratory number of group.	Date of exposure.	Place and condition of exposure.	Exposures averaged.	Colonies developed.	
				Open field.	Barn-yard.
	1897				
139	March 10	30 rd. from any building	4	$\frac{3}{4}$	...
176	April 24	On post 6 rd. from barn, just after shower ...	2	0	...
177	"	Same as No. 176, only at foot of post	2	0	...
227	June 3	3 ft. from ground	1	...	4
236	"	3 ft. from damp ground, no breeze	1	...	0
237	"	Same as No. 236, only on ground, slight breeze	1	...	80
238	"	Same as No. 237, only air quiet	2	...	3
255	"	On post 6 ft. from barn, wind from barn	1	...	18
256	"	On post, wind blowing across pasture	1	2	...
257	"	3 ft. from ground, 1 rod east of barn	1	...	4
274	July 2	On ground, 1 rod east of barn	2	...	$2\frac{1}{2}$
276	"	Same as No. 274, only on post	3	...	$1\frac{2}{3}$
279	"	On ground	2	...	5
281	"	Same as No. 279, only on post	1	...	1
325	Sept. 14	On post, 1 rod east of barn	1	...	1
326	"	Same as No. 325, only on ground	1	...	1
359	"	On post in dusty yard, wind from cows	2	...	12
398	Oct. 28	In dusty yard, wind from grassy field.	4	...	17
402	"	In dusty yard among cows, no breeze	4	...	86
406	"	In dusty yard after cows were let out.....	1	...	46
	1899				
613	May 11	Gentle breeze, shower night previous	14	$\frac{5}{4}$	...
634	May 14	On ground in barnyard	10	...	$2\frac{1}{2}$
639	"	On ground in grassy pasture.....	12	$\frac{1}{6}$	...
895	June 3	On ground in barnyard	10	...	$1\frac{9}{10}$
905	"	On ground in grassy pasture.....	8	$3\frac{3}{8}$	...
917	Sept. 16	On ground in barnyard	3	...	$6\frac{1}{3}$
		Average		0.9	13

Table 1 shows the average number of colonies that developed in petri dishes from exposures made at different times in the open field and in the barnyard.

By referring to the column containing the results of exposures made in the open field, it is seen that the group averages range from 0 to $3\frac{3}{4}$ colonies, and that the average of the entire forty-three exposures was less than one colony. From the last column, which shows the results of exposures made in the barnyard, it is seen that the group averages range from 0 to 86 colonies, with an average for the fifty-one exposures of 13 colonies. Of the exposures made in the open field, fifty percent were sterile, while of those made in the barnyard only twelve percent were sterile, showing that the air in the open field was comparatively free from bacteria, while that in the barnyard, where the ground was bare and dusty, contained more.

BACTERIAL CONDITION OF AIR IN DAIRY BARN.

The two following tables show the results from exposures made in dairy barns varying in their sanitary condition and care. They also show the effect upon the bacterial content of the air of the different common operations performed in dairy barns.

TABLE 2.—DAIRY BARN No. 1.

Frame barn, 30 x 50 ft., containing two rows of cows; tight floor overhead; plank floor under cows; dirt floor back of cows; cobwebs numerous.

Laboratory number of dish.	Date of exposure.	Place and condition of exposure.	Number of colonies developed.
	1897		
232	June 15	Barn vacant, open, air still, floor dry	5
233	"	Barn vacant, open, air still, floor dry	33
234	"	Barn vacant, open, air still, floor dry	19
235	"	Barn vacant, open, air still, floor dry	50
		Average	27
240	"	After cows were let in	150
241	"	After cows were let in	54
242	"	After cows were let in	44
243	"	After cows were let in	24
		Average	68
245	"	After No. 240, in window, wind blowing out	44
246	"	Same as No. 245, only another window.....	208
		Average	126
247	"	In window, opposite side, wind blowing in.....	4
248	"	Same as No. 247, only another window	44
		Average	24
250	"	Back of cows, 3 ft. from floor, 30 min. after No. 240..	34
252	"	Back of cows on floor, 30 min. after No. 240.....	36
253	"	4 ft. from floor between two rows of cows	150
254	"	On floor	718

DAIRY BARN No. 2. H. B. GURLER.

Barn 50 x 60 ft., containing four rows of cows; cement floor, wooden stalls, sides and ceiling whitewashed. Milking in progress.

332	Oct. 20	Middle of west end, cows eating grain and silage	2
336	"	Northwest corner	51
337	"	Northeast corner, wind blowing in	16
340	"	Northwest corner	37
341	"	Southeast corner	29
342	"	Middle of barn.....	23
343	"	Middle of barn.....	86
344	"	Middle of barn.....	18
345	"	Middle of barn, just after letting out cows.....	30
346	"	Middle of barn, just after letting out cows.....	26
		Average	32

In Table 2 the result of each exposure is given, and the average of each group is shown in heavy type.

June 15, when the barn had been vacant, but open for six hours, and the air was comparatively still out of doors, four exposures averaged 27 colonies, for so much of the floor was dry and dusty that the air in the barn was far from sterile. After the cows were let in, four exposures averaged 68 colonies, indicating that letting in the cows had increased the bacterial content of the air two and one-half times. Immediately following these, two exposures in a window, wind blowing out, averaged 126 colonies, which is nearly twice as many as were obtained from an average of four exposures made at different places in the barn just before. Two exposures in a window, wind coming in, averaged 24 colonies, showing that the air was not badly infected when entering the barn, but that it became so while there.

Exposures Nos. 250 and 252, made back of the cows, showed 34 and 36 colonies, while at the same time two exposures made in feed alley between rows of cows showed 150 colonies three feet from the floor, and 718 on the floor, from which it appears that there were many more bacteria in the center than at the sides of the barn, and more at the floor than three feet above.

From the results obtained in this barn we learn that with a dry and dusty floor the bacterial content of the air is high when the cows are in the barn, even though they are not brushed and no hay or bedding is moved.

At the time the ten exposures were made in dairy barn No. 2, the barn was full of cows eating grain and silage and four men were milking. The number of colonies that developed in the different dishes ranged from 2 to 86, with an average of 32. This difference was doubtless due to local conditions, as a cow switching her tail near the exposed dish might send myriads of bacteria into the air at that place. The low average shows that the air was comparatively free from bacteria for a barn full of cows and when milking was in progress. This condition was, no doubt, due to the fact that the barn was built and cared for in a most sanitary manner. An excellent system of ventilation was provided, the cement floor was scrubbed clean every day, sides and ceiling were whitewashed and no cobwebs were allowed to collect.

TABLE 3.—BACTERIAL CONDITION OF AIR IN DAIRY BARN No. 3.

Stone basement, 32 x 40 ft., containing two rows of cows; tight floor above, paved floor below; an inch of dusty chaff on floor; cobwebs numerous.

Laboratory number of group.	Date of exposure.	Place and condition of exposure.	Exposures averaged.	Colonies developed.
351	1897 Oct. 25	Just before cows were let in; barn vacant all day, except 8 calves in end	6	152
363	"	Immediately after cows were let in	5	202
371	"	1 hr. after No. 363	6	192
381	"	30 min. after No. 371, just after letting out the cows	4	150
387	Oct. 28	Conditions same as No. 351	6	126
394	"	Window sill, slight breeze blowing in from empty yard	2	30
396	"	After No. 394, in open door, wind blowing out ..	2	75
408	"	Same as No. 394, only 5 min. later, cows having been let in barn in meantime	2	39
410	"	Same as No. 408, only in door on opposite side, wind blowing out	2	66
412	"	30 min. after cows were let in; exposures made in different parts of barn	6	129
422	"	30 min. after No. 410, in door wind blowing out ..	2	325
424	"	30 min. after No. 408, same window, brisk breeze blowing in from vacant yard	2	77
426	"	5 min. after No. 422, in door wind blowing out, cows let out in meantime	2	321
428	"	In yard below window where No. 424 was exposed.....	1	76

DAIRY BARN No. 4, UNIVERSITY OF ILLINOIS.

73	Feb. 13	After sweeping and feeding, cows eating roughage		94
78	"	1½ hr. after No. 73, a little bedding put in 20 min. previous	4	
83	"	20 min. after No. 78, 6 cows brushed in meantime	5	72
90	Feb. 23	After feeding chopped fodder and sweeping, dust visible	2	692
96	"	40 min. after No. 90; barn quiet in meantime, except cows eating	6	84
104	"	25 min. after No. 96; 13 cows brushed in meantime.....	6	61
121	March 10	After feeding and sweeping; doors open, strong wind from south	10	159
127	"	1 hr. after No. 121, barn open in meantime, strong breeze from south	5	40
133	"	20 min. after No. 127; 10 cows brushed in meantime, barn open, windy	6	84
152	April 24	Cows in, eating oat hay; barn closed and swept..	6	44
158	"	1 hr. after No. 152; barn quiet except cows eating hay	6	57
164	"	20 min. after No. 158; 11 cows brushed in meantime.....	4	119
170	"	10 min. after No. 164; barn quiet in meantime..	5	131
			1	53

TABLE 3.—BACTERIAL CONDITION OF AIR IN DAIRY BARN No. 4—Continued.

Laboratory number of group.	Date of exposure.	Place and condition of exposure.	Exposures averaged.	Colonies developed.
178	1897			
184	May 4	Cows in, eating hay; barn closed for 15 min.	6	62
190	"	20 min. after No. 178; 8 cows brushed in meantime.....	6	92
206	"	15 min. after No. 184; barn quiet in meantime ..	3	59
218	June 3	Barn quiet, cows let in, all quiet 15 min.; small amount of bedding in stalls.....	9	46
268	"	20 min. after No. 206; 11 cows brushed in meantime.....	6	88
285	July 2	10 cows in, brushed, quiet 15 min., windows open on one side, no wind, damp outside.....	6	12
316	July 10	Cows in, bedded, and fed hay; no rain, and very hot for 10 days	2	55
465	Sept. 14 1898	Milking in progress	3	276
471	Nov. 30	Barn empty, swept, and closed for 3 hours; snow on ground 3 days	6	1 236 291 412 84 858 7½ 0 29 33 800 600 20 4½ 6 764 123 150
477	"	10 min. after No. 465	6	
478	"	30 min. after No. 465; cows let in, fed chopped fodder; floor swept, dust slightly visible.....	1	
479	"	30 min. after No. 465; cows let in, fed chopped fodder; floor swept, dust slightly visible.....	1	
480	"	30 min. after No. 465; cows let in, fed chopped fodder; floor swept, dust plainly visible.....	1	
488	"	30 min. after No. 465; cows let in, fed chopped fodder; floor swept, no dust visible.....	7	
498	"	1 hr. after No. 480; cows eating in meantime. ...	9	
931	"	10 min. after No. 488; 16 cows brushed in meantime.....	2	
282	1901			
283	June 5	Milking in progress; no hay moved for 1 hr.; barn open, slight breeze	12	
284	1897			
322	July 2	On floor, south door of barn, slight breeze from south, 5 cows in barn.	1	0
497	"	On floor, center of barn, no breeze	1	29
487	"	On floor, north door of barn, no breeze	1	33
500	1897			
512	Sept. 14	3 ft. from cow being brushed	2	800
516	1898	3 ft. from cow being brushed	1	600
522	"	Feed room after corn meal was let down from bin above, much dust visible	1	20
524	"	Feed room after corn meal was let down from bin above, much dust visible	4	4½
	"	10 min. after No. 500	2	6
	"	Behind 8 cows just after being brushed 4 min.; less dust visible than at No. 500	4	764
	"	5 min. after No. 516	2	123
	"	10 min. after No. 516	2	150

TABLE 3.—BACTERIAL CONDITION OF AIR IN DAIRY BARN No. 4—Continued.

Laboratory number of group.	Date of exposure.	Place and condition of exposure.	Exposures averaged.	Colonies developed.
566	1899 April 13	Behind cows, milking in progress.....	2	60
592	May 11	Behind cows, milking in progress.....	4	8½
628	May 14	Feed room after musty corn meal was let down from bin above	2	284
630	"	Barn loft 3 min. after hay was moved, small amount of dust visible	4	7½
700	May 16	On floor back of cows, milking in progress.....	8	8½
713	May 19	Barn loft after pitching hay, dust plainly visible.	4	323
717	"	Same place as No. 713, 3 min. later.....	4	45
725	"	Immediately after No. 717, on beam 8 ft. above.	2	27
721	"	Same place as No. 717, 3 min. later	4	22
727	"	In feed room after corn meal was let down from bin above, dust plainly visible	4	57
731	"	Same place as No. 727, 3 min. later	4	15
735	"	Same place as No. 731, 3 min. later	4	12
739	"	In feed room after bran was let down from bin above, dust slightly visible	4	418
743	"	Same place as No. 739, 3 min. later	3	6
830	May 28	On floor back of cows, milking in progress.....	2	4
832	"	In front of cows, milking in progress.....	3	11
850	June 3	On floor back of cows, milking in progress.....	5	3½
885	"	After bran was let down from bin above, dust slightly visible	5	114
890	"	Same place as No. 885, 6 min. later	5	8½
927	Sept. 16	On floor back of cows, milking in progress.....	4	19

October 25 and 28, exposures were made in a barn that had been vacant all day excepting eight calves in one end. From the number of colonies which developed it is seen that when the barn floor is dry and dusty, and cobwebs are allowed to collect, the bacterial content of the air is high if there are animals moving about. In such cases the number of bacteria is increased but slightly by letting in the cows.

These results show that under normal conditions air which enters windows and doors is comparatively sterile, while that which passes out is badly contaminated.

Barn No. 4 in Table 3 was the University dairy barn before being remodeled.

The floor of the barn was swept each day and no cobwebs were allowed to collect. From the group averages, Nos. 268, 465, 471, and 931, it is seen that the bacterial content of the air in the barn was low, even though the cows were in if they were quiet and no hay or bedding had been moved for some time. Immediately after bedding or feeding roughage the number of bacteria in the air was much greater, while an hour later it was reduced about one-third. There were occasional exceptions to this, as in the three groups on March 10, when all door and windows were open. At the same time there was a strong breeze blowing, rapidly replacing the dusty air with air from out of doors, which was nearly sterile.

To show the effect of having the barn quiet, November 30 all stock was let out, windows and doors closed, and the barn locked for three hours, after which an average of six exposures gave only one-half a colony; ten minutes later, after having moved about in the barn, an average of six exposures gave but five-sixths of a colony. This shows that when the air in the barn remains perfectly quiet for some time, it becomes comparatively sterile.

Half an hour after letting in the cows and feeding and sweeping, one exposure, where dust was plainly visible, showed 412 colonies, and eleven exposures made at different places in the barn where there was no dust visible, averaged 151 colonies. These results show the number of bacteria that are in the air as a result of feeding and sweeping when the air was nearly sterile before. One hour later nine exposures averaged 84 colonies, showing that the dust and bacteria soon settled out of the air. Ten minutes later, sixteen cows brushed in meantime by two men, an average of two exposures gave 858 colonies, showing that brushing the cows had increased the bacterial content of the air over ten times.

Even though the number of bacteria caught when the cows were eating hay was large, the increase caused by brushing the cows varied from a small amount in one case to over ten times the number in another case, the only exception being when there was a strong breeze blowing through the barn, for in such cases the results are especially uncertain.

From the table it is seen that the number of bacteria in the air is greatly increased by brushing the cows, and it may also be noticed that the bacteria rapidly settled by allowing everything to remain quiet for from ten to twenty minutes.

From the latter half of Table 3, beginning with exposure No. 322, it is seen that dust arising from different sources in dairy barns may be similar in amount and yet differ greatly in bacterial content. The average of four exposures made where dust from each of the following sources was plainly visible, contained colonies as follows: corn meal, 57; hay, 323; bran, 418, and from brushing cows, 764. It is seen from this

that dust which comes from brushing cows contains about twice as many bacteria as that from either hay or bran, and thirteen times as many as dust from corn meal. This is doubtless due to the fact that bacteria find on the cow a good place to develop, as both warmth and nutriment are present. The dust from hay comes from the external and exposed parts of plants, and since bran is from the external portion of the wheat kernel it is natural that the dust from these be heavily laden with bacteria, as the exposed parts of all plants are more or less covered with these organisms. Since the great bulk of corn meal comes from the inner portion of the kernel, which is sterile, it is not strange that dust from fresh corn meal contains but few bacteria compared with that from other feeds. The two exposures in dust from musty corn meal, in group No. 628, averaged 284 colonies, while an average of four exposures in fresh corn meal gave in one case 57 colonies, and in another $4\frac{1}{2}$ colonies, showing that dust from musty corn meal contains bacteria in much larger numbers than dust from fresh corn meal, as bacteria multiply greatly during the process of fermentation.

Exposures made a few minutes after a dust had been raised showed in each case that much had settled from the air, and that where there was no movement to keep up a dust, the air soon became comparatively sterile.

TABLE 4.—BACTERIAL CONDITION OF EXPERIMENTAL MILKING ROOM, UNIVERSITY OF ILLINOIS.

Laboratory number of group.	Date of exposure.	Place and condition of exposure.	Exposures averaged.	Colonies developed.
257	1897 June 25	Floor damp, sides dry, window open, damp out-doors	4	0
261	July 2	Window closed, cloudy and damp	7	$1\frac{3}{4}$
289	July 10	Small window open all day, slight breeze	4	$6\frac{3}{4}$
295	"	5 min. after No. 289, sides and ceiling sprinkled with hose in meantime.....	3	11
300	"	Cow being brushed 3 ft. distant	1	6174
301	"	After cow had been brushed 4 min. and removed; room quiet 4 min.	2	147
305	"	30 min. after No. 301, room quiet and closed in meantime	3	$5\frac{1}{2}$
429	Nov. 13	After room had been closed 6 hours	6	$7\frac{5}{8}$
435	"	10 min. after No. 429, just after sprinkling sides and ceiling with hose	6	19
441	"	50 min. after No. 435, room closed in meantime ..	6	$4\frac{1}{2}$
447	"	2 min. after No. 441, cow brought in and brushed 1 min.	2	262
449	"	After cow had been brushed 4 min. and removed from room	4	32
453	"	3 min. after cow had been removed	2	11
455	"	7 min. after No. 453	6	3
461	"	8 min. after No. 455	2	0

The results of exposures, shown in Table 4, were obtained in an experimental milking room where the conditions were more completely under control than in the barn; the purpose being to determine the condition of the air in a room that had been vacant for some time, also after sprinkling the sides and ceiling with a hose, immediately after brushing a cow, and at frequent intervals thereafter.

From this table it is seen that June 25, when the floor of the milking room and the outside air were damp, four exposures were sterile, and July 2 seven exposures averaged $1\frac{6}{7}$ colonies.

A series of exposures was made under varying conditions July 10 and November 13, and from these it is seen that somewhat fewer colonies developed upon entering a room than after thoroughly sprinkling the sides and ceiling with a hose, as the force of the water seemed to raise a slight dust. This, however, settled rapidly, for as soon as the dust touched any wet surface it adhered to it. July 10 a cow was brought into the nearly sterile air of the room, brushed four minutes, and removed, when exposure No. 300 was made and 6,174 colonies developed. An average of two exposures, group No. 447, made after a cow had been brushed one minute, gave 262 colonies, showing again that the dust which comes from cows is heavily laden with bacteria. It is noticed in both of these cases that the dust rapidly settled when the room remained closed so that there were no currents of air, and in the course of half an hour the air was practically free from bacteria.

TABLE 5.—BACTERIAL CONDITION OF AIR IN DAIRY ROOMS, UNIVERSITY OF ILLINOIS.

Laboratory number of group.	Date of exposure.	Place and condition of exposure.	Exposures averaged.	Colonies developed.	
				Front room.	Bottling room.
	1897				
10	Jan. 13	On table	2	15	....
11	"	On table	2	..	$\frac{1}{2}$
12	"	On table, milk cooling	2	..	0
175	April 24	On table, room closed for 30 min.....	2	..	0
327	Sept. 14	On table, milk cooling	3	..	$\frac{1}{3}$
330	"	On table	1	14	..
	1899				
621	May 11	On table, room empty	24	..	$\frac{1}{12}$
625	"	On table, room empty	18	..	$\frac{1}{4}$
708	May 16	On table when bottling milk.....	5	..	$2\frac{1}{5}$
913	Sept. 16	On table when bottling milk.....	4	..	$\frac{1}{2}$

Table 5 shows the average number of colonies developed from exposures made in dairy rooms which have cement floors and painted sides and ceilings. From the three exposures made in the front room, which is used both as an office and separating room, the average number of colonies developed was 15. In the bottling room everything is kept

TABLE 6.—COLONIES DEVELOPED FROM EXPOSURES UNDER UDDERS IN VARIOUS CONDITIONS.

Laboratory number of group.	Date of exposure.	Number of exposures averaged.	Average number of colonies developed; different udders.		Average number of colonies developed; same udder before and after treatment.				Six feet behind cows.
			Unwashed.	Washed.	Before washing.	After washing.	Before wiping.	After wiping.	
	1897								
198	May 4	3	....	486	....	....	....	....	....
313	Sept. 14	3	....	219	....	....	....	....	....
319	"	3	1031	....	....	....	....	....	....
331	Oct. 20	3	....	200	....	....	....	....	....
526	Dec. 8	8	....	....	2973	....	....	....	....
534	"	4	....	....	....	90	....	....	....
	1899								
538	April 13	16	....	....	470	....	....	....	....
554	"	11	....	....	....	133	....	....	....
566	"	2	....	....	....	....	....	....	60
568	May 11	6	....	....	421	....	....	....	....
574	"	6	....	....	....	226	....	....	....
580	"	6	....	....	211	....	....	....	....
586	"	6	....	....	....	88	....	....	....
592	"	4	....	....	....	....	....	....	8½
651	May 16	5	....	....	230	....	....	....	....
656	"	4	....	....	....	25	....	....	....
671	"	4	....	....	157	....	....	....	....
676	"	10	....	....	....	72	....	....	....
686	"	3	....	....	372	....	....	....	....
690	"	8	....	....	....	152	....	....	....
700	"	8	....	....	....	....	....	....	8¼
746	May 23	5	....	....	25	....	....	....	....
751	"	10	....	....	....	48	....	....	....
761	"	5	....	....	90	....	....	....	....
766	"	10	....	....	....	11	....	....	....
776	"	4	....	....	127	....	....	....	....
781	"	9	....	....	....	58	....	....	....
791	"	2	....	....	....	....	....	....	6
793	May 28	4	....	....	144	....	....	....	....
799	"	10	....	....	....	286	....	....	....
811	"	5	....	....	116	....	....	....	....
817	"	9	....	....	....	269	....	....	....
830	"	2	....	....	....	....	....	....	4
835	June 3	15	33	....	....	....	....	....	....
850	"	5	....	....	....	....	....	....	3
855	"	15	....	20	....	....	....	....	....
870	"	15	....	27	....	....	....	....	....
920	Sept. 16	3	....	23	....	....	....	....	....
923	"	4	56	....	....	....	....	....	....
927	"	4	....	....	....	....	....	....	19
	1901								
943	June 5	4	....	....	....	....	2301	....	....
947	"	8	....	....	....	....	....	503	....
955	"	3	....	....	1756	....	....	....	....
958	"	6	....	....	....	512	....	....	....
964	June 14	2	....	....	....	....	1614	....	....
967	"	2	....	....	....	....	....	291	....
973	"	2	....	....	....	....	1026	....	....
976	"	4	....	....	....	....	....	369	....
996	June 22	5	....	....	....	....	1586	....	....

TABLE 6.—COLONIES DEVELOPED FROM EXPOSURES UNDER UDDERS IN VARIOUS CONDITIONS.—Continued.

Laboratory number of group.	Date of exposure.	Number of exposures averaged.	Average number of colonies developed; different udders.		Average number of colonies developed; same udder before and after treatment.				Six feet behind cows.
			Unwashed.	Washed.	Before washing.	After washing.	Before wiping.	After wiping.	
1001	June 22	10	....	....	....	....	....	346	....
1011	"	4	1401	....	....	....	....	....	....
1016	June 24	5	....	....	....	....	482	....	....
1021	"	10	....	....	....	....	....	118	....
1031	"	4	....	....	....	....	120	....	....
1036	"	10	....	....	....	....	....	123	....
1046	"	5	....	....	....	....	202	....	....
1051	"	10	....	....	....	....	....	133	....
1061	"	5	....	....	....	....	94	....	....
1066	"	8	....	....	....	....	....	229	....
1095	June 27	5	....	....	....	....	266	....	....
1100	"	9	....	....	....	....	....	421	....
1110	"	4	....	....	....	....	114	....	....
1115	"	9	....	....	....	....	....	262	....
1125	"	3	....	....	....	....	448	....	....
1130	"	8	....	....	....	....	....	193	....
1140	June 28	5	....	....	....	....	329	....	....
1145	"	10	....	....	....	....	....	191	....
1155	"	4	....	....	....	....	849	....	....
1160	"	9	....	....	....	....	....	313	....
1170	"	5	....	....	....	....	314	....	....
1175	"	10	....	....	....	....	....	407	....
Number of exposures averaged			26	42	74	103	58	117	27
Average			362	83	615	148	630	270	12

scrupulously clean, and the floor is usually damp, thus keeping the greater part of the dust out of the air." Sixty exposures were made in this room at different times of the year, and the average for the total number was one-third of a colony. More than half of all colonies developed from the bottling room were from five exposures made when bottling milk; forty-seven of the sixty exposures in this room were sterile. In other words, a dish would have to be exposed an average of one and a half minutes to catch one bacterium. In an atmosphere as nearly sterile as this, milk becomes contaminated very slowly, even where a large surface is exposed, as in passing over a cooler.

To learn something of the amount of contamination that takes place during milking, and how much this may be reduced by washing the udders, 420 petri dishes were exposed under washed and unwashed udders. The average number of colonies developed from exposures made under washed udders was 192 and under unwashed udders 578, or three times as many. The group averages from these exposures are shown in Table 6.

As a rule, washing udders makes a marked reduction in the number of colonies developed from exposures made under them. This difference is much greater in some cases than in others. The most noticeable



CUT 5.—IN MID-WINTER. PROPERLY CLEANED, TO, PREVENT ALL POSSIBLE CONTAMINATION

difference was obtained December 8, when an average of eight exposures, No. 526, showed 2,973 colonies before washing, while an average of four exposures made under the same udder after washing showed only 90 colonies. In other words, the contamination which took place in this instance was thirty-three times greater before washing than after.

In a few cases a less number of colonies developed from exposures made under unwashed udders than from those made under the same udders after washing. A possible explanation for this is that dirt from

the unwashed udders fell in larger particles, and thus the dishes were contaminated in fewer places, although a greater total contamination took place, for a colony developed on a petri dish may have originated



CUT 6.—AFTER A RUN OF THREE WEEKS ON PASTURE. IMAGINE THE SOURCE OF CONTAMINATION DURING WINTER.

from a single bacterium or from a particle of dirt large enough to be seen with the naked eye and containing thousands of bacteria.

It should be borne in mind that the udders used in this experiment were not only apparently clean, but they had been washed regularly each day before milking, and in all probability there was much less dirt adhering to them than to udders that had never been washed. With soiled or muddy udders, such as are frequently found in dairies, the benefits derived from washing are much greater than these results show.

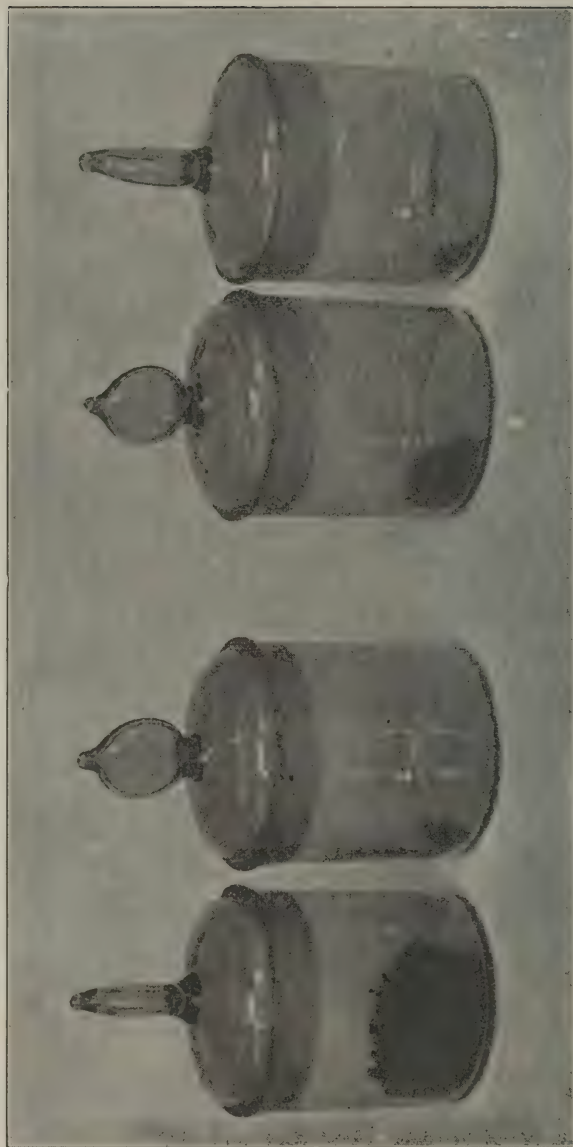
TABLE 7.—WEIGHT IN GRAMS OF DIRT WHICH FELL FROM UDDERS DURING TIME OF MILKING.

Udders apparently clean.				Udders slightly soiled.				Udders muddy.			
Date.	Before washing.	After washing.	Ratio of washed to unwashed.	Date.	Before washing.	After washing.	Ratio of washed to unwashed.	Date.	Before washing.	After washing.	Ratio of washed to unwashed.
May 20.....	.0395	.0081	4.88	May 20.....	.0682	.0062	11.00	July 18.....	.3025	.0105	28.81
" 20.....	.0230	.0075	3.06	July 3.....	.0303	.0041	7.39	" 24.....	.3997	.0038	105.18
July 2.....	.0297	.0061	4.87	" 18.....	.0429	.0054	4.12	" 25.....	.4273	.0075	56.97
" 2.....	.0056	.0061	-1.09	" 18.....	.0579	.0054	10.72	" 28.....	.7088	.0160	44.30
" 2.....	.0122	.0055	2.22	" 31.....	.1841	.0120	15.33	" 30.....	.7520	.0088	85.45
" 3.....	.0056	.0075	-1.34	" 31.....	.0761	.0057	13.35	" 31.....	.9921	.0068	145.89
" 7.....	.0072	.0027	2.67	" 31.....	.1210	.0121	10.00	" 31.....	.5586	.0162	34.48
" 7.....	.0025	.0019	1.31	Aug. 6.....	.0502	.0087	5.77	" 31.....	.2899	.0073	39.71
" 9.....	.0079	.0028	2.82	" 6.....	.0985	.0075	13.13	Aug. 25.....	.6651	.0044	151.15
" 9.....	.0030	.0037	-1.23	" 7.....	.0929	.0108	8.60	" 26.....	.5977	.0158	37.83
" 9.....	.0370	.0040	9.25	" 7.....	.0817	.0033	24.75	" 26.....	.2634	.0149	17.68
" 11.....	.0145	.0038	3.81	" 26.....	.1150	.0067	17.27	Oct. 6.....	1.3110	.0058	226.03
" 11.....	.0063	.0045	1.40	Sept. 23.....	.1428	.0100	14.28	" 6.....	2.2156	.0061	363.21
" 11.....	.0023	.0014	1.64	" 23.....	.1023	.0045	22.73	" 21.....	1.2213	.0059	207.00
" 12.....	.0023	.0016	1.44	Oct. 6.....	.1716	.0065	26.40	" 21.....	1.5150	.0078	194.23
" 12.....	.0184	.0034	5.41	" 21.....	.1171	.0039	30.25	" 24.....	1.4813	.0050	296.26
" 15.....	.0196	.0030	6.53	" 21.....	.0057	.0080	6.96	" 24.....	1.7553	.0085	206.51
" 17.....	.0107	.0026	4.11	" 24.....	.1648	.0139	11.86	April 18.....	.9512	.0103	92.35
" 21.....	.0237	.0089	2.66	" 24.....	.2387	.0058	41.15	" 18.....	.8096	.0112	72.28
" 21.....	.0347	.0135	2.57	Nov. 1.....	.2838	.0065	43.66	" 18.....	.9192	.0103	89.24
" 21.....	.0023	.0013	1.77	" 1.....	.1811	.0040	45.27	" 18.....	.5528	.0147	37.16
" 24.....	.0193	.0040	4.82	" 1.....	.1163	.0094	12.37	" 21.....	1.2507	.0091	51.47
" 26.....	.0370	.0029	12.72	" 1.....	.2946	.0080	36.82	" 21.....	.6293	.0142	44.31
Aug. 7.....	.0024	.0016	1.50	" 1.....	.3337	.0050	66.74	" 21.....	.5750	.0160	35.94
Sept. 23.....	.0127	.0025	5.08	April 18.....	.1697	.0098	17.31	" 21.....	.9342	.0090	17.23
Average ..	.0152	.0044	3.5	Average ..	.1316	.0079	18	Average ..	.8831	.0098	90

AMOUNTS OF DIRT CAUGHT UNDER WASHED AND UNWASHED UDDERS DURING MILKING. THE GLASS WEIGHING TUBES SHOWN BELOW ARE NATURAL SIZE.

UDDER MUDDY. BEFORE WASHING. AFTER WASHING.

UDDER SLIGHTLY SOILED. BEFORE WASHING. AFTER WASHING.



CUT 8.—THE AVERAGE WEIGHT OF DIRT WHICH FALLS FROM MUDDY UDDERS DURING MILKING IS 90 TIMES AS GREAT AS THAT WHICH FALLS FROM THE SAME UDDERS AFTER WASHING, AND WHEN UDDERS ARE SLIGHTLY SOILED IT IS 18 TIMES AS GREAT. SEE PAGE 243.

WEIGHT OF DIRT WHICH FALLS INTO MILK DURING MILKING.

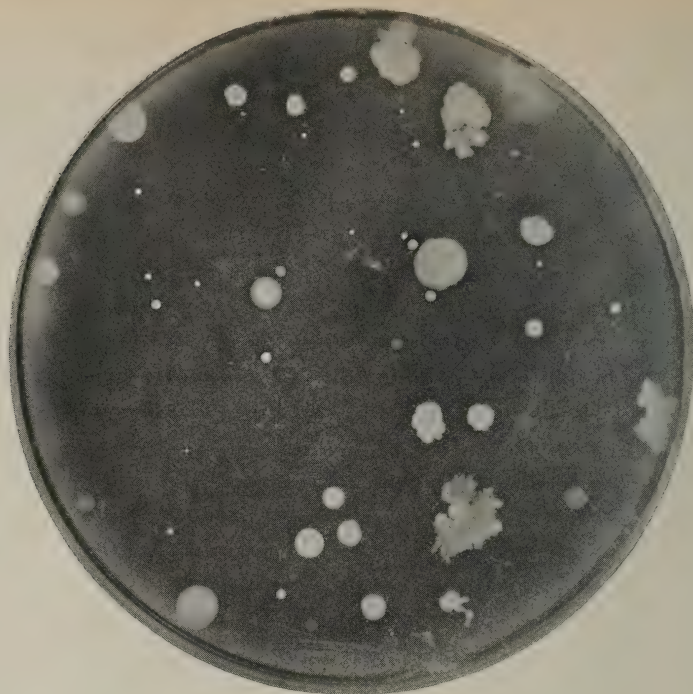
The results shown in Table 7 were obtained for the purpose of determining by weight the amount of filth which falls into milk during the process of milking, and how much this may be reduced by washing the udders.

After several trials with three different milkers on thirty cows, it was found that it required an average of $4\frac{1}{2}$ minutes to milk a cow. A glazed dish, eleven inches in diameter, the size of an ordinary milk pail, was held under a cow's udder $4\frac{1}{2}$ minutes, while the milker went through motions similar to those made in milking, but not drawing any milk. The amount of dirt which fell into the dish during the operation was, of course, approximately the same as would have fallen into the milk during the milking process. The dirt caught in the dish was then brushed into a small glass weighing tube, such as shown in cut 9, the udder washed, and the process repeated. Both tubes were then placed in a desiccator, and after drying twenty-four hours to remove moisture, were accurately weighed in a chemical balance.

It will be noticed that the weight of dirt which fell from udders varied greatly when there appeared to be the same amount on them. The reason for this is that the amount of dirt which falls from a clean, a soiled, or a muddy udder depends upon the character of the dirt, the amount of hair on the udder, its shape, the length of the teats, etc.

Seventy-five trials were made at different seasons of the year with three classes of udders, those apparently clean, soiled, and muddy. With udders that were apparently clean, it was found that an average of $3\frac{1}{2}$ times as much dirt fell from the unwashed udders as from the same udders after they were washed. With soiled udders the average was 18, and with muddy udders 90 times as much dirt from the unwashed as from the washed.

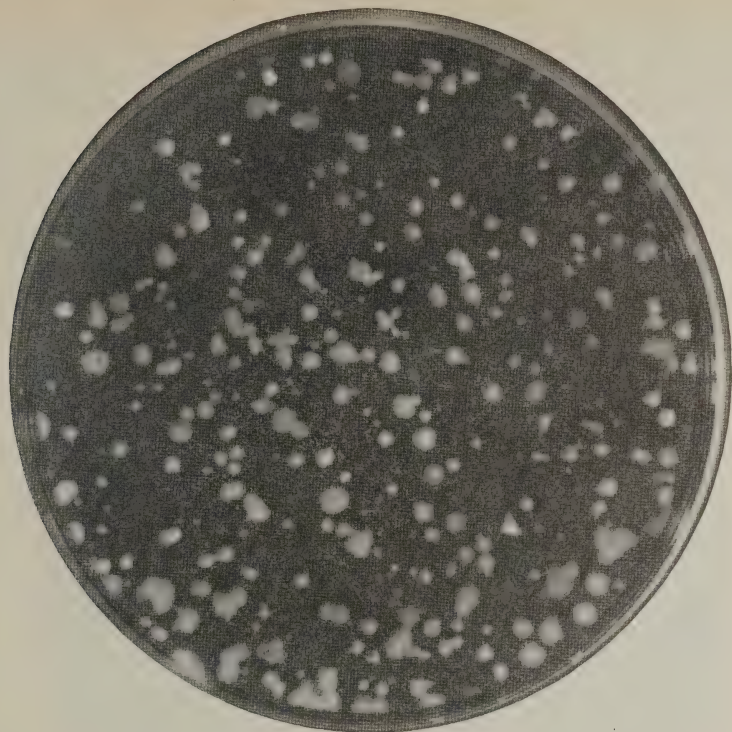
The average weight of dirt falling from muddy udders during the time of milking was found to be .8831 of a gram. Since in one ounce there are $28\frac{1}{2}$ grams, an ounce of dirt would fall into the milk for every 32 milkings. From a year's records, kept by the department of dairy husbandry, of eight herds containing 144 cows, it was found that one gallon, or $8\frac{3}{4}$ pounds, was the average yield at a milking. On this basis, in 32 milkings, 275 pounds of milk would be produced containing one ounce of filth. With the same udders after they were washed, 24,030 pounds of milk, or 90 times as much, could be obtained before the amount of filth it contained would reach one ounce. This shows the decided advantage, in the production of clean milk, of washing the udders before milking.



CUT 9.—PETRI DISH, SHOWING COLONIES DEVELOPED FROM EXPOSURE DURING MILKING IN WELL-KEPT DAIRY BARN.

TABLE 8.—AVERAGE NUMBER OF COLONIES DEVELOPED FROM EXPOSURES MADE IN DIFFERENT PLACES AND TIME MILK WOULD HAVE TO STAND AT THOSE PLACES TO RECEIVE AS MUCH CONTAMINATION FROM THE AIR AS IT WOULD UNDER AN UNWASHED UDDER DURING THE $4\frac{1}{2}$ MINUTES OF MILKING.

Place of exposure.	Number of exposures averaged.	Average number colonies developed from $\frac{1}{2}$ min. exposure.	Ave. number min. milk would have to stand at the different places to receive as much contamination from the air as it would under an unwashed udder during the $4\frac{1}{2}$ min. of milking.	Time in days.
Open field.....	43	$\frac{9}{10}$	2890	2
Barnyard	51	13	200	..
Well kept barn during milking ..	10	32	81	..
University barn during milking ..	46	38	68	..
Poorly kept barn during milking ..	21	168	15	..
Barn empty, closed 3 hours	12	$\frac{3}{3}$	3901	$2\frac{2}{3}$
Before feeding	9	46	57	..
After feeding	34	109	24	..
After brushing cows	38	307	8	..
Under apparently clean unwashed udder.....	158	578	$4\frac{1}{2}$	..
Under washed udder	262	192	14	..
Bottling room	60	$\frac{1}{1}$	7803	$5\frac{2}{3}$
Dairy front room.	3	15	173	..



CUT 10.—PETRI DISH, SHOWING COLONIES DEVELOPED FROM EXPOSURE DURING MILKING IN POORLY KEPT DAIRY BARN.

CONCLUSIONS.

The results of the work described in this bulletin are of vital importance to the practical dairyman, as they show that extreme cleanliness is absolutely essential to the most successful dairying.

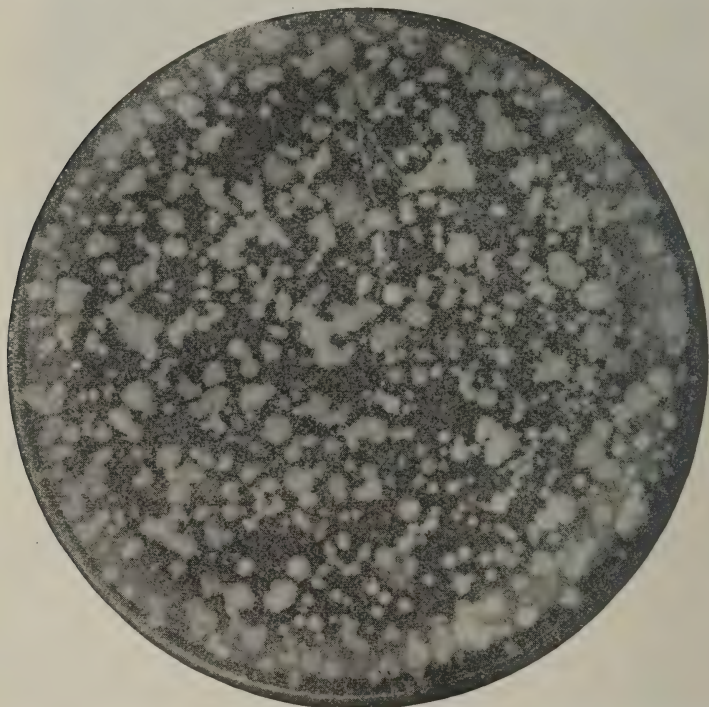
Table 8, which contains averages of all exposures made in different places, shows where and under what conditions milk becomes contaminated most rapidly, and that the bacterial content of milk may be greatly reduced by a few simple precautions easily carried out in any dairy. The nearer the ideal condition is reached, the fewer bacteria in the milk, and the more wholesome will be not only the milk itself, but the products made from it, and the better their keeping quality.

From exposures made out of doors it was found that air in the open field was nearly sterile, since an average of less than one colony developed for each half-minute exposure, while in the barnyard an average of 13 colonies developed in the same time. This increase over the number in the field was doubtless due to the fact that the ground in the barnyard was bare and dry, and the cows moving about created a dust.

In a well-kept dairy barn, where the floor was swept clean and no

cobwebs were allowed to collect, 32 colonies developed from exposures made when milking was in progress, and in a poorly kept barn, where there was much dust on the floor and cobwebs were numerous, 168 colonies developed, or five times as many. This shows the decided advantage of keeping the dairy barn as clean as possible.

To show the effect of having everything in the milking stable quiet for some time, the University dairy barn was swept, after the cows were



CUT 11.—PETRI DISH, SHOWING COLONIES DEVELOPED FROM EXPOSURE UNDER APPARENTLY CLEAN UNWASHED UDDER.

let out, and closed for three hours; exposures then made showed an average of less than one colony.

When the cows were in, but before feeding, 46 colonies developed for each half-minute exposure; immediately after feeding roughage 109 colonies developed, and after brushing the cows the number was increased to 307. These results indicate that feeding roughage and brushing cows greatly increase the bacterial content of the air. Such operations, therefore, should not take place immediately before milking, but some time should intervene to allow the dust to settle.

By far the greatest source of contamination in milk is the cow herself, and the greater part of this contamination comes from the udder, unless that is washed before milking. The one hundred fifty-eight

exposures made under unwashed udders averaged 578 colonies, or three times as many as the average number developed from exposures made under the same udders after washing. Table 7, giving the weight of dirt caught under udders in different conditions, shows that three and one-half times as much dirt fell from apparently clean unwashed udders as from the same udders after washing. Thus it is seen that in the case of apparently clean udders the ratio of the weight of dirt caught corre-



CUT 12.—PETRI DISH, SHOWING COLONIES DEVELOPED FROM EXPOSURE UNDER WASHED UDDER.

sponds very closely with the ratio of the number of colonies developed from exposures under washed and unwashed udders. The amount of contamination from soiled or muddy udders was not determined from a bacteriological standpoint; the benefit derived from washing such udders was determined only by the comparative weights of dirt caught under them. With soiled udders the weight of dirt was eighteen times greater from the unwashed udders than from the same udders after washing, and with muddy udders it was ninety times greater.

In the University of Illinois dairy rooms, which have cement floors and painted sides and ceilings, there are comparatively few bacteria in the air. This is especially true of the milk bottling room, where the floor

is frequently scrubbed, and is usually damp, as an average of sixty exposures showed only one-third of a colony.

From the averages in the preceding table it is seen that the amount of contamination that milk receives from the bacteria of the air falling into it, depends entirely upon the conditions under which it was exposed. The table also shows the length of time it would take milk exposed in the pail to receive the same amount of contamination at the designated places that it gets from an unwashed udder during milking,



CUT 13.—PETRI DISH, SHOWING COLONY DEVELOPED FROM EXPOSURE IN MILK BOTTLING ROOM.

which time was found to be $4\frac{1}{2}$ minutes. Since an average of 578 colonies developed on sixty-three square centimeters of surface for every half-minute exposure under an unwashed udder, in $4\frac{1}{2}$ minutes the number would have increased to 5,202. In the milk bottling room an average of one-third of a colony developed on a like area for every half-minute exposure, or two-thirds per minute. A pail of milk would, therefore, have to stand exposed to the air in this room 7,803 minutes, or more than five days, to receive as much contamination as it would under an apparently clean unwashed udder during milking. This emphasizes not only the great importance of washing the udders before

milking, but also of having the dairy rooms and all surroundings as clean and the air as free from dust as possible wherever dairy products are handled.

An effort was made to determine the different species of bacteria that gain access to milk, but in the present state of development of the science of bacteriology, this is difficult to do satisfactorily. For the practical dairyman it is sufficient to say that a majority of the forms found grow readily in milk. Many of the species produce visible changes in milk, such as curdling or peptonizing, while others affect the flavor.

It should be borne in mind that a great majority of the species of bacteria that gain access to milk do not possess the power to produce disease, and are not injurious to healthy adults, although many of them are likely to produce disorders of digestion in infants and invalids.

Paying special attention to cleanliness in every step of the production and care of milk will result not only in clean milk, but in a marked reduction in the number of bacteria it contains, which will greatly lengthen its keeping qualities. That the desired results may be obtained, care must be constantly exercised. It is of little consequence to practice extreme cleanliness in all of the steps of milk production but one, and be filthy about that one, as this spoils the whole. Even if the majority of species of bacteria which ordinarily gain access to milk are not dangerous to health, no one cares to consume milk in which a sediment is found at the bottom if it is allowed to stand for a short time. Frequently much filth is allowed to get into milk during milking, and many milkers practice the filthy habit of keeping the teats wet with milk during the milking process, yet after it is drawn the greatest care is exercised that no dust or dirt gain access to it. As far as the final result is concerned, all painstaking care in the subsequent operations is lost because of the careless work at the beginning during the process of milking, for if filth once gains access to milk, no amount of care afterwards can remedy the difficulty. It is, therefore, of the greatest importance to the advancement of better dairying that special emphasis be placed upon the operation where milk is liable to receive the most contamination. The work reported in the preceding pages shows that the greatest source of contamination in milk, as ordinarily produced, is the cow herself, and this is doubly important because it is the source which is given the least attention in actual practice.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

BULLETIN NO. 92.

CITY MILK SUPPLY.

By WILBER J. FRASER.



URBANA, ILLINOIS, DECEMBER, 1903.

INTRODUCTION.—Owing to the many evils resulting from the use of impure milk, the public has recently taken special interest in the subject of city milk supply, and because of this interest Bulletins 91 and 92 are published at this time. Page 253.

THE CONSUMER'S INTERESTS.—The consumer is interested in having milk of a known composition, free from germs, clean, of good flavor, thoroughly cooled, and held at a low temperature. Page 255.

CARE OF THE YARD.—A yard sloping from the barn and covered with gravel or cinders is an important factor in the production of clean milk. Page 255.

THE STABLE.—This building need not be of costly construction, but it should be arranged with a view to cleanliness and the comfort of the cows. Page 255.

LIGHT AND VENTILATION.—An abundance of light and fresh air is necessary to the economic production of wholesome milk. Page 258.

ADVANTAGES OF WHITEWASH.—Whitewashing the stable at least once a year will aid greatly in keeping it in a sanitary condition. Page 258.

CLEANLINESS IN MILKING.—Milk, as ordinarily produced, gets the greatest amount of contamination from the udders. Washing them before milking will do much to prevent this. Page 259.

CARE OF MILK.—Cooling milk to 50° F. or below as soon as it is drawn checks the action of bacteria, thus adding to the keeping quality of the milk. Bottling milk at the dairy prevents contamination during delivery and subsequently. Page 259.

CARE OF DAIRY UTENSILS.—Thoroughly washing and sterilizing dairy utensils after each using adds to the safety and keeping quality of milk. Page 262.

STANDARD MILK.—Milk having a certain known composition, and sold on the basis of its food value, is known as "standard" milk. Page 263.

STANDARDIZING MILK AND CREAM.—This process consists in adding or removing an amount of butter fat necessary to bring the percent to the desired standard. Page 263.

CERTIFIED MILK.—Standard milk produced under sanitary conditions certified to by the producer is called "certified" milk. Page 267.

CONSUMER'S RESPONSIBILITY.—Keeping milk cool and protecting it from dust and odors after delivery is of as great importance as its proper production. Page 270.

IMPROVING CONDITIONS.—By adopting as many sanitary methods as possible, and gradually increasing them, a steady progress will be made. Page 270.

NEED OF INSPECTION.—Judicious inspection would be of untold advantage to the consumer and of decided benefit to the better class of dairymen, and they should at once take active steps to have such a system instituted. Page 272.

CITY MILK SUPPLY.

BY WILBER J. FRASER, CHIEF IN DAIRY HUSBANDRY.

INTRODUCTION.

The statements made in this bulletin are the result of seven years' experience in conducting a sanitary dairy at the University of Illinois, where the milk is bottled and delivered for direct consumption. They are also the result of investigations in the contamination of milk reported in Bulletin No. 91. Both of these bulletins and Circular No. 73 are published at the present time because of the recent interest manifested by the public in city milk supply.

The methods commonly employed in the production of milk are so faulty, and the evils resulting from the use of impure milk so numerous and of such a serious nature, that every one interested in the public welfare should be anxious to bring about an improvement. In many cities and towns of the State, much attention is paid to the water supply, and large sums of money are expended in obtaining good and pure water; yet in most cities no attention is given to the quality of milk furnished, which to many, especially the children, is of even greater moment than the water supply. In but few cities of the State is it possible to get a regular supply of milk that has been produced under really clean conditions, thoroughly cooled and bottled in a proper manner, and which parents feel sure is safe for infant feeding. Among the reasons why a reform should be instituted are the following:

No other article of food is so generally used by all classes of people.

About one-third of all the milk produced by the 17,000,000 cows in the United States is sold for direct consumption, and much of it is consumed in its raw state.

No other food is more healthful and economical than milk when pure, and none is more dangerous to health when carelessly handled.

Milk being an opaque liquid, its quality and cleanly condition cannot be easily detected by its appearance.

Many infants and invalids subsist almost, if not entirely, upon milk, and it is of vital importance that milk for such persons be as pure and free from bacteria as possible.

Milk is an ideal medium for the growth of germs; because of this fact it is especially important that it be handled with the greatest care so that no disease germs may be allowed to gain access to it.

Since the invention of the Babcock test and the cream separator, dairymen can easily standardize the milk and cream they sell, and should be required to do so.

To secure desired results care must be exercised at every step of milk production and delivery. There is little use in observing all but one of the precautions here suggested for the production of high grade milk, as this one neglect spoils the whole.

Even by exercising the greatest care in the production of milk, it cannot be secured in a commercial way from the cow, germ free. It is for this reason that it must be protected from further contamination and kept at a low temperature during delivery and subsequently, or the bacterial content will soon be enormous.

The efforts that have been made to induce dairymen to use more sanitary methods in handling their milk have often resulted in failure. One important reason for this is not hard to find, for milk cannot be produced under sanitary conditions as cheaply as in the common slovenly manner, and when the price of the product is raised, the consumer, not appreciating the added value to himself, often objects to paying the advanced price. This naturally discourages further efforts toward improved methods in production. When consumers insist on having milk of known quality and purity, and are willing to pay a slightly advanced price for it, such milk will be supplied.

If its true food value were more fully appreciated, milk would be used much more freely than it now is, to the advantage of both the health and economical sustenance of the people. A quart of three percent milk, costing five cents, will furnish about the same amount of nutrition as three-fourths of a pound of meat, costing nine cents; yet people invariably consider milk something of a luxury, and think they are economizing by restricting its use as much as possible, although they buy meat freely, considering it one of the necessities of life. Few people realize that the elements needed to nourish the body may be obtained from milk more cheaply than from meat, and that milk takes the place of other foods, thus diminishing the quantity of other food needed.

The public has long been defrauded by dishonest and unscrupulous milk dealers, and has suffered from the slovenly methods of the careless dairyman. The honest dealers who furnish clean milk have been and are still having a hard fight with dishonest competition and the indifference of the public. The most effective remedy for this difficulty is for the public to patronize those only who furnish a good grade of milk, and are willing to guarantee it.

It is the aim of this bulletin to bring the consumers and the better class of dairymen together; to show both the importance of handling milk in a cleanly, sanitary manner; also to present to dairymen improved methods of handling milk and delivering it to the vast number of people living in our cities. There is yet much to be learned along this line, but certain facts are well established, and it is of these that this bulletin is to treat.

THE CONSUMER'S INTERESTS.

The consumer is especially interested in five things in connection with his milk supply, and for these the producer should be responsible:

First, that the milk be clean.

Second, that the milk keep at least twenty-four hours after being delivered to the consumer, if held at a temperature of 60° or below.

Third, that the flavor of the milk be not injured by improper feeding, careless methods in handling, or by the development of certain species of bacteria which cause bad flavors.

Fourth, that the milk be not injurious to health; that it contain no disease-producing germs or any form of preservative.

Fifth, that the milk have a certain known composition which is uniform from day to day.

The consumer has a right to demand that milk furnished him meets the above requirements, and unless it does, he should refuse to take it.

In order that milk may conform to the above requirements, the following suggestions as to the care of the barn, cows, dairy, utensils, etc., must be carried out.

CARE OF THE YARD.

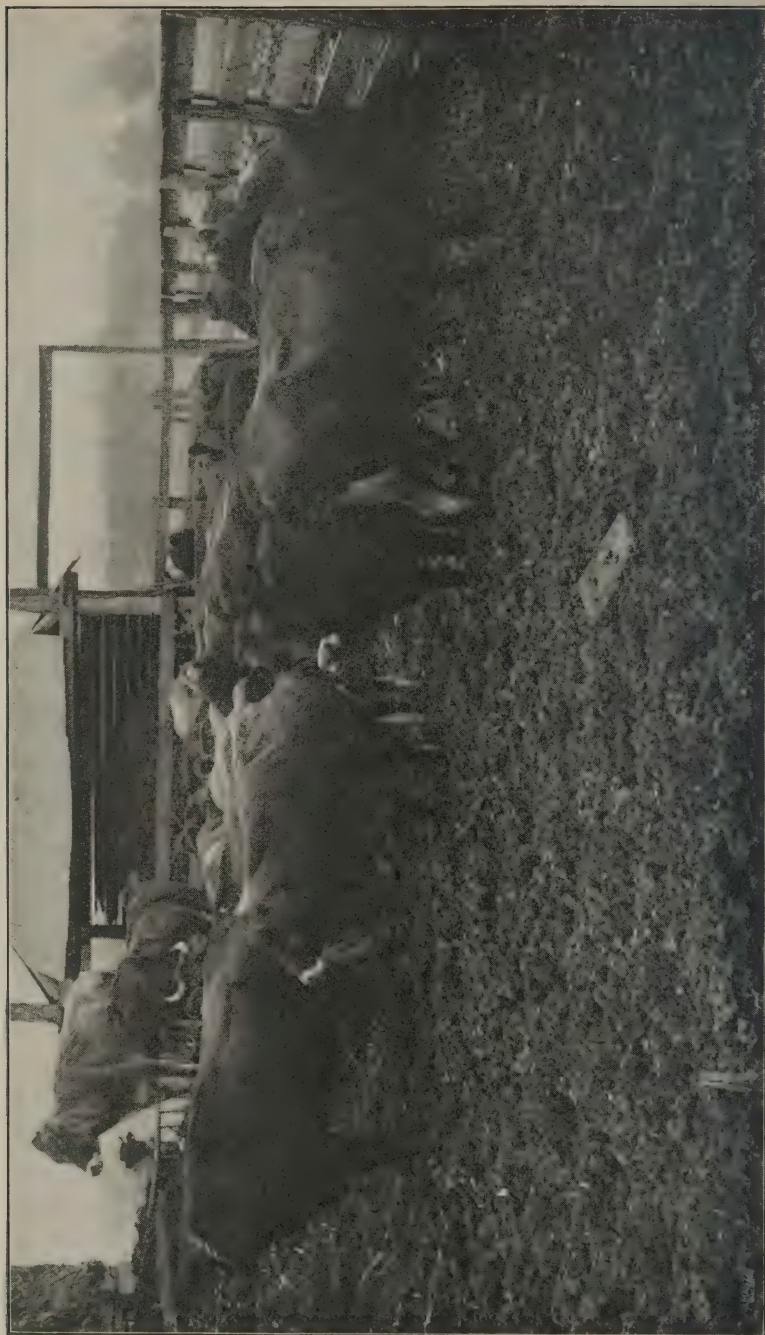
In the production of clean milk no one thing is of more importance than keeping the cows out of the mud and filth of a dirty barnyard. The yard should be graded to slope gently from the barn, and should be covered with gravel or cinders sufficiently deep to form a hard surface. In this way the cows will be kept out of the mud, thus preventing their bellies and udders from becoming soiled.

It is advisable to haul the manure directly to the field from the barn, but if this is not feasible it should be removed at least one hundred feet from the barn. In no case should it be allowed to accumulate against or near the dairy barn, and no swine pen should be nearer than two hundred feet, since the odors are readily absorbed by milk.

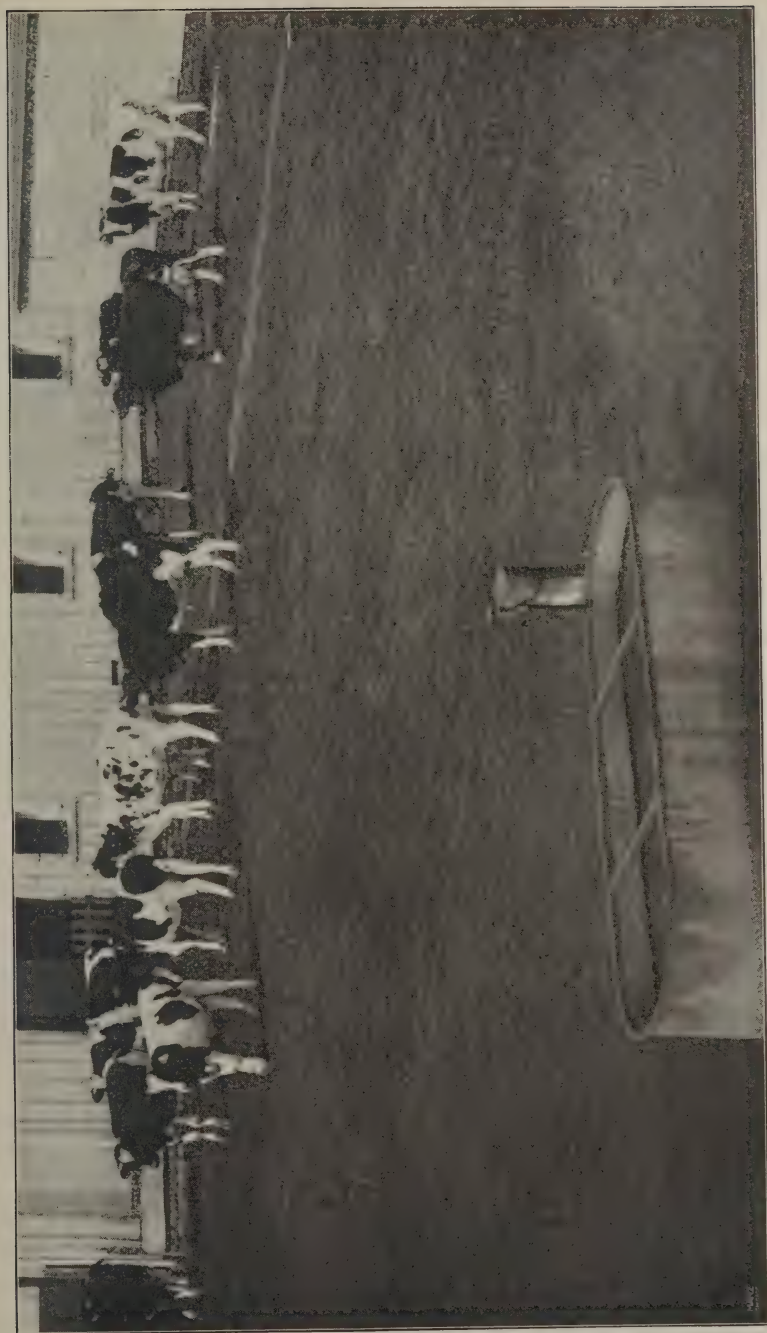
BARNs AND STABLES.

Costly barns or stables are not essential to the production of clean milk or to the maintenance of a dairy herd at its highest efficiency. To obtain the best results, it is important, however, that the cows be kept comfortable at all times. To do this there are several essentials with which a barn must be provided. It must have a roof that does not leak, sides that do not allow the wind to blow through, and doors that will close tightly.

It is of the utmost importance in keeping cows clean that the platform on which they stand be of the proper length. If it is too short, the cows cannot lie down comfortably, and if too long, the droppings will fall



CUT 1.—AN UNGRADED YARD IN WHICH THE MANURE IS ALLOWED TO ACCUMULATE.



CUT 2.—A WELL-GRADED YARD COVERED WITH SIX INCHES OF CINDERS.

on the rear of the platform and the cows will become soiled when lying down. As cows vary in length, the platform should be longer from the manger to the gutter, at one end of the barn, and gradually taper to six or eight inches shorter at the other end. When large herds are kept, the platform on one side of the barn may be longer than on the other side, and the cows arranged accordingly. A still better arrangement is some form of movable manger so that the length of the platform can be adjusted to suit each individual cow. With this arrangement all can be lined up on the gutter, which will be a great help in keeping the cows clean.

LIGHT AND VENTILATION.

Two things almost universally lacking, or at least inadequately supplied in dairy barns, are light and pure air. These are easily obtained, and although absolutely essential to the best health of the herd and the economic production of clean milk, they are rarely appreciated. There should be from three-fourths to one and one-half square feet of glass for every linear foot of outside wall in a dairy barn.

Many barns are not provided with any system of ventilation whatever, as but few dairymen realize that pure air is just as essential to the economic production of untainted milk as is the feed a cow consumes. Digestion and assimilation, like the burning of coal in a stove, are processes of combustion. The stove may be filled with coal, but if the drafts are kept tightly closed, the coal will not burn, as sufficient oxygen is not provided. Neither can a cow's feed be properly digested and assimilated without an abundance of oxygen, and unless this is supplied, a great waste of food, as well as impaired health of the cow, will result.

Much has been said about the number of cubic feet of air space that should be allowed for a cow, but this is of little consequence in comparison with the more important question of ventilation, or change of air. In order not to get a greater degree of impurity in the air than is permissible with good results, each cow should be supplied with 3,540 cubic feet of air an hour. The size of the ventilating flues to be provided will depend upon the number of cows in the stable. About two feet square is a good size, and if so constructed as to cause the air to move three hundred feet a minute, this will furnish ventilation for twenty cows. Two flues this size would be sufficient for forty cows, and five would be required for one hundred cows.

ADVANTAGES OF WHITEWASH.

To be sanitary a dairy barn should be whitewashed at least once a year. An interior like the one shown in cut 3, with a few boards laid overhead at irregular intervals, with hay hanging through, and with the sides and ceiling in no better condition, cannot be properly whitewashed. The ceiling should be tight, excluding all dust and chaff from above, and

the sides should be smooth, thus affording a firm surface to which the whitewash can cling.

Whitewash is one of the cheapest disinfectants, and can be easily and rapidly applied with a spray pump. It must be carefully strained before using in the pump, as any lumps will clog the spray nozzle.

CLEANLINESS IN MILKING.

In the production of milk for direct consumption, it is imperative that the udders be clean before milking, as it is from soiled udders that milk as ordinarily produced gets the greatest amount of contamination.

In Table 7, Bulletin 91, is given the weight of dirt which fell from washed and unwashed udders during milking. From this it is seen that with udders that were apparently clean, an average of three and one-half times as much dirt fell from the unwashed udders as from the same udders after they were washed. With soiled udders the average was eighteen, and with muddy udders the average was ninety times as much dirt from the unwashed as from the same udders after washing.

These averages clearly show that all udders must be washed before milking if high-grade milk of good keeping quality is to be produced.

THE CARE OF MILK.

As soon as it is drawn milk should be removed from the stable to a place provided for the purpose, and there aerated and cooled to 50° F., or below if possible. This should be done either by setting the cans into a tank of cold water, and stirring occasionally, or by passing the milk over a cooler. The latter method is to be preferred if the cooling can be done in a pure atmosphere free from dust. It is of great importance to have a small milk-house, or some clean room away from the odors of the stable, in which to care for the milk.

The sooner milk is thoroughly cooled after it is drawn, and the lower the temperature to which it is brought, the better. Bacteria that get into milk during the process of milking develop very rapidly as long as milk remains at about the temperature at which it was drawn, but as soon as cooled to 60°, they develop slowly, and if cooled to 40° their growth is almost entirely stopped. Milk cooled to this temperature as soon as drawn, and held there, will remain sweet and in good condition much longer than if cooled to only 70° or 75°.

Dairymen who deliver milk in cans, measuring out the amount wanted at each door, sell with the milk the dust and germs that collect in the measures as they drive along the street. To prevent contamination during delivery and subsequently, all milk must be bottled in the dairy. Some dairymen bottle milk in the wagon on the route, using bottles collected from houses just visited. This dangerous practice cannot be too strongly condemned, and should be prohibited by law. If

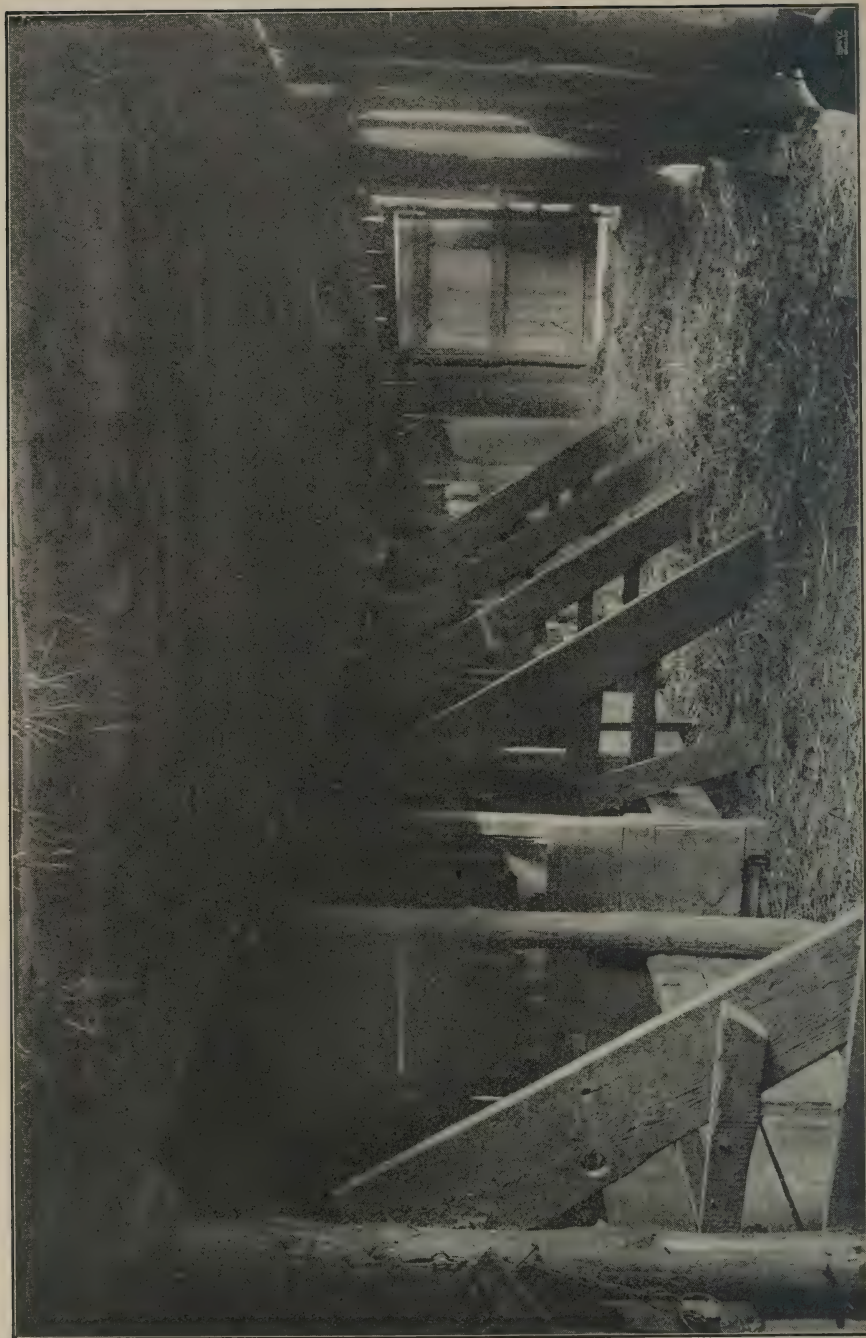
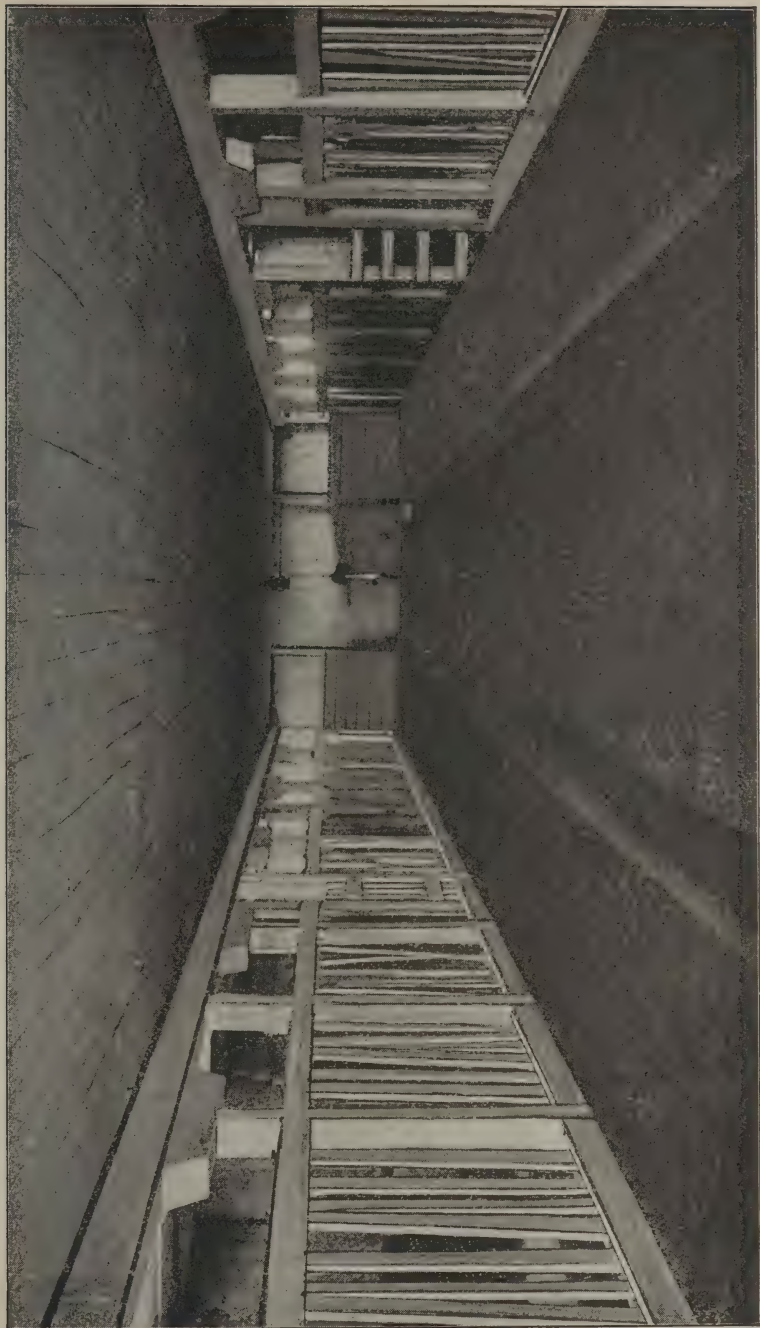


FIG. 2. RAMP ON MINE CHARACTER ARE ENTIRELY TOO NUMEROUS.

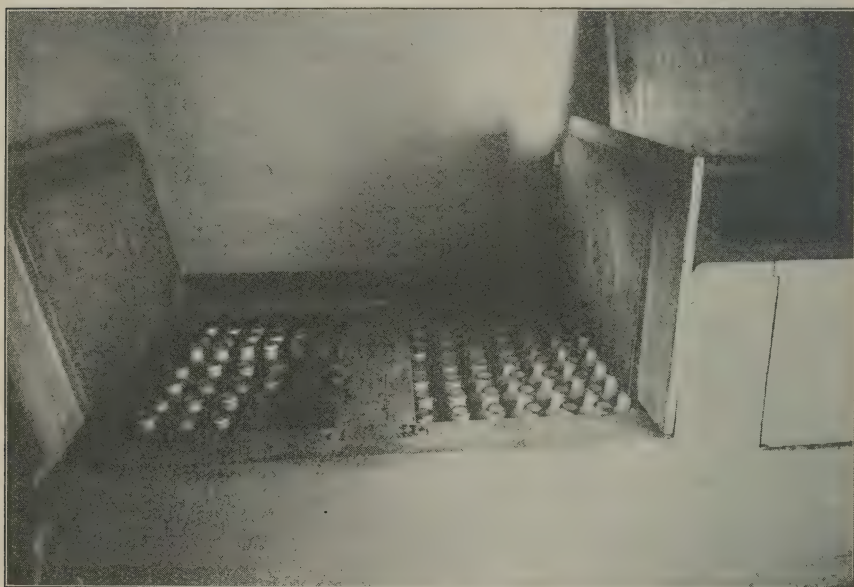


CUT 4.—A SANITARY BARN, CLEAN AND WHITEWASHED.

the bottles are not taken to the dairy and washed and sterilized before being filled, milk delivered in bulk is safer, although possibly not so clean.

CARE OF DAIRY UTENSILS.

One of the first essentials in keeping dairy utensils clean is to have vessels with smooth surfaces. This fact should be kept in mind when purchasing, and if all seams are not flushed smooth with solder, this should be done. All utensils should be of tin, and as soon as the tin is worn off on the inside, they should be discarded, for they cannot be



CUT 5.—BOTTLED MILK HELD IN ICE-WATER IN REFRIGERATOR UNTIL DELIVERED.

properly cleaned when in this condition. All utensils should be washed as soon as possible after using, since the longer the milk remains on them, the harder they will be to clean. They should first be rinsed with lukewarm water to remove the milk, then washed with hot water and soap, or some alkali, and scalded with boiling water, or with steam if it is available. Cans should never be tightly closed when not in use, and should be placed on a rack in an inverted position so that the dust cannot blow into them. If possible, they should be placed where the sun will shine on them, as that will do much toward keeping them pure and sweet.

Bottles used to deliver milk for direct consumption must be taken to the dairy after each using and thoroughly washed and sterilized to kill all disease germs. If this is not done, disease may be carried from one house to another by means of the bottles.

STANDARD MILK.

By standard milk and cream is meant that which has a certain known composition, thus establishing a true basis for valuation.

Let it be clearly understood by producers, consumers, city councils, and everybody that in these days the dealer can furnish the customer with milk of any desired richness, without regard to the quality ordinarily yielded by the cow, and all milk should be either so standardized or else bought and sold according to its natural composition.

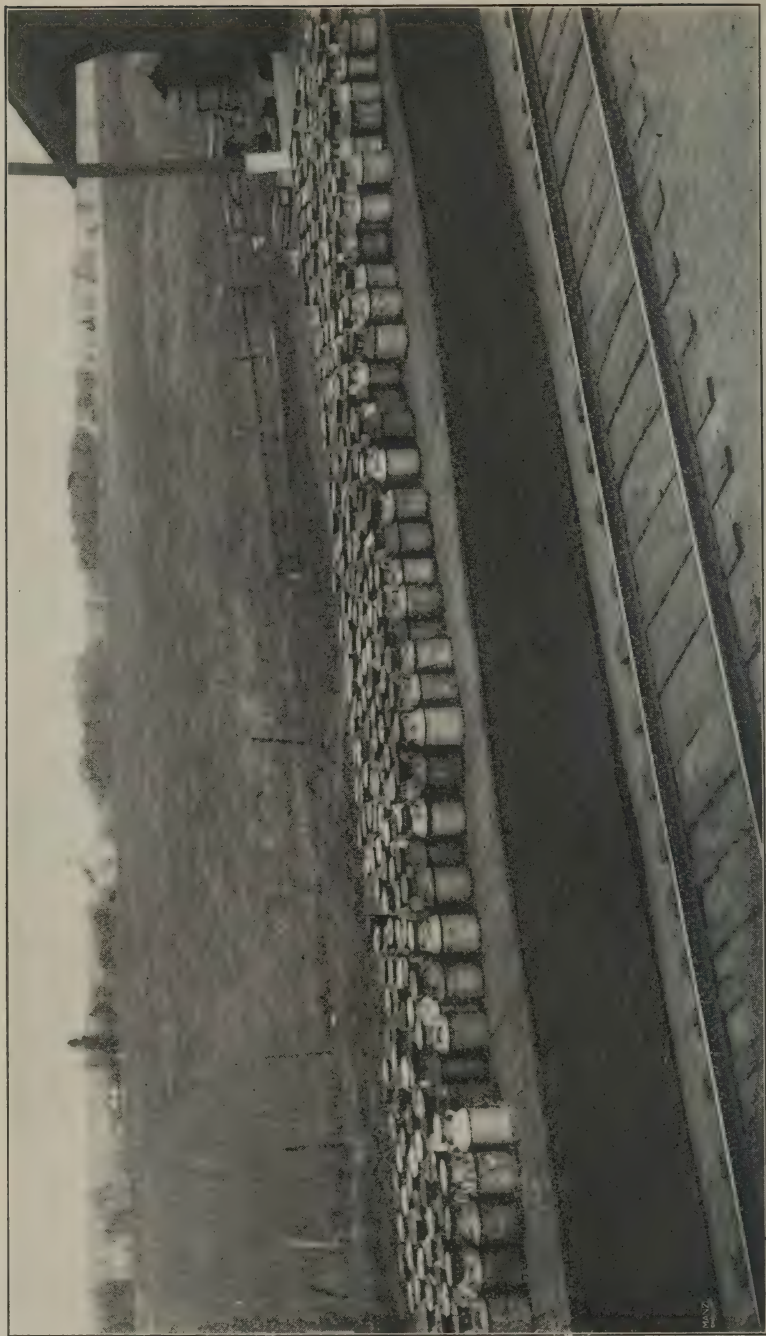
Selling milk by measure alone is unjust to the producer as well as to the consumer. While the fallacy of the system is apparent to a few, the majority of people seem to think that milk is milk, and that one quart is worth as much as another, so long as it is still sweet. The reason for this is partly a lack of knowledge as to what constitutes good milk, and partly because milk is an opaque liquid, and it is difficult to judge of its composition or food value simply by appearance. For this reason, many unscrupulous milk dealers dilute their milk with water or remove a portion of the cream.

State legislatures and city councils have attempted to overcome this difficulty by passing laws and ordinances making it unlawful to change the composition of milk. Where these laws were enforced, they stopped the dilution of milk to a great extent, but did not tend to compel milk dealers to sell milk of any known composition or on the basis of its food value.

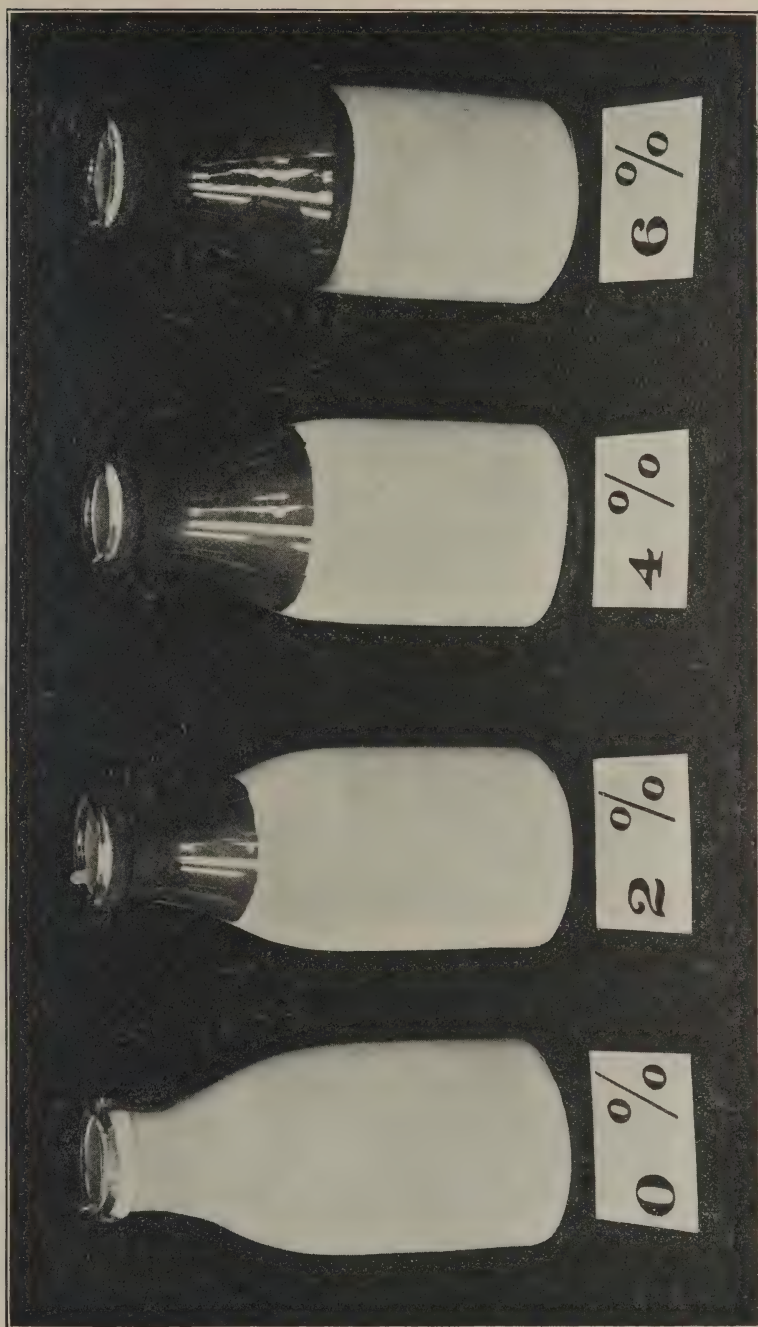
The next attempt to remedy the difficulty was to fix a certain standard, below which it was unlawful to sell milk. Most of the states and some cities passed laws to this effect. These standards seldom require more than three percent fat and twelve percent total solids. The city or state standards, even where they exist, have not reached the difficulty, as they make the sale of milk coming direct from some individual cows that give milk low in fat, unlawful, while it is good, wholesome milk, and a perfectly legitimate product when sold at its proper price. But what is even worse, this system hinders the man who produces rich milk from getting the price he should according to its food value and cost of production. Milk containing a high percent of fat is not only worth more for food, but costs more to produce than milk containing a low percent of fat, and the price should be governed by its composition and food value and not by its bulk.

STANDARDIZING MILK AND CREAM.

Since fat in milk is the most variable constituent, the other solids remaining fairly constant, standardizing milk is a comparatively simple matter. All that is necessary is to add or remove a certain amount of butter fat, which is easily done by means of the centrifugal separator,



CUT 6.—MILK CANS AT THE RAILWAY STATION.



CUT 7.—STANDARDIZED MILK, SHOWING THE AMOUNT OF CREAM ON MILK CONTAINING THE DESIGNATED PERCENT OF BUTTER FAT.

or by letting the cream rise by gravity. While it is true that milk from individual cows varies somewhat from day to day, the mixed milk of a herd that is milked at regular times each day will be practically constant for that herd, because all of the cows will not test high or low on the same day. By testing the milk of a herd occasionally, the percent of fat in the milk may be known at all times with reasonable accuracy, together with the amount of butter fat that should be added or removed to bring it to the proper standard. If the separator does good work, and the amount of milk handled is small, so that it does not warrant testing every day, it may be run very close to the desired percent of fat by testing once a week, so as to be sure that it is up to the required standard. Where the quantity of milk handled is large, it is more economical to run tests frequently, and keep the fat at exactly the desired percent. Even if the percent of fat varies but slightly, it makes a great difference in profit in the course of the year in a large business. If 1,000 gallons of milk are sold daily at the price given in Table 1, and the percent of fat in the milk is 4.5, when only 4 percent milk is required, the loss to the one selling the milk is $1\frac{1}{2}$ cents a gallon, or \$15 a day; this in a year would amount to \$5,475.

The only apparatus necessary to standardize milk is a cream separator and a Babcock milk test. Surely no dairyman who has a business of any consequence can afford to be without these machines. For dairymen handling but a small amount of milk, the same results may be accomplished by setting the milk for a time, and skimming off the cream. In this case all that is necessary is a Babcock test, which may be obtained from any milk supply house for four dollars. In this work, skim milk containing practically no fat must be added or removed. If the skim milk used contains fat, proper allowance must be made according to the amount of fat contained, or the results will obviously be different. Water cannot be used to dilute the milk or the percent of solids not fat will be reduced.

As the percent of albuminoids, milk sugar, and mineral matter are practically the same in milk containing different amounts of butter fat, these are not considered in the following table. From this table it will be seen that if all milk were standardized, and sold according to these prices, dairymen would then receive the legitimate price for their product according to its food value and cost of production, and would not be selling six percent milk in competition with three percent milk and for the same price a quart. Such a method would result in justice to both producer and consumer.

TABLE 1.—RELATIVE VALUE A QUART AND NUMBER OF QUARTS IN A DOLLAR'S WORTH OF MILK OF THE FOLLOWING COMPOSITION AS TO FAT, COMPUTED ACCORDING TO THE FOOD VALUE OF 3 PERCENT MILK AT 5 CENTS A QUART.

Percent of fat	0.1	1	2	3	4	5	6
Price a quart, cents	2.8	3.5	4.2	5.0	5.7	6.5	7.2
Number of quarts a dollar...	35.7	28.6	23.8	20.0	17.5	15.4	13.9

CERTIFIED MILK.

The grade of milk known as "certified" is nothing more than milk of a known composition, as clean and free from bacteria as science and skill can make it, and produced by an inspected herd.

Even in the production of this grade of milk, costly buildings are not necessary, but they should be so constructed as to be easily cleaned, and must be kept in perfect condition. The stable must be cleaned frequently, at least twice a day, when the cows are indoors, and all feeding of dry fodder, bedding, and sweeping must be completed not less than fifteen minutes before beginning to milk, thus allowing time for the dust to settle. Before milking all udders must be washed, whether they appear soiled or not, and the milkers must wash their hands and put on clean suits of some washable material. As soon as drawn, the milk must be removed from the stable to a sanitary dairy, where it is cooled to 50° F. or below, standardized, and bottled. The bottles and all other utensils with which the milk comes in contact must be thoroughly washed and sterilized after each using.

When milk is produced in a manner similar to that described in this bulletin, a public statement should be made certifying to the methods of production and the percent of fat contained. Such milk finds a ready market at an advanced price when its true value is understood.

The easiest and most effective way of letting the patrons know the advantages of high grade milk, and the methods used in its production, is by means of an illustrated circular. This circular should show views in the dairy barn and dairy, describe how the herd is kept, and the milk produced and prepared for the trade. It should be neat and attractive in form, as well as brief and to the point, so that it may be easily read. Copies should be distributed among the patrons, and, together with samples of the milk advertised, given to the influential people of the town. The physicians should be called upon and some means devised for getting them to visit the dairy. If they find everything there in first-class condition, they will not be slow in recommending the milk to their patients. The patrons, too, should be encouraged to visit the dairy where it is possible for them to do so. Few, doubtless, can be induced to pay a personal visit, and the great advantage of the circular is that it



CUT 8.—FEEDING ALLEY IN A SANITARY DAIRY BARN WHERE CERTIFIED MILK IS PRODUCED.



CUT 9.—REAR VIEW, SAME BARN.

will not only reach all the patrons, but it will help greatly in extending the trade.

As an illustration of such a circular, one published several years ago showing the methods used in the University dairy, is reprinted in connection with this bulletin as Circular No. 73. Such a circular will do much to inform the public where good, clean milk can be obtained, and to bring the well-conducted dairies into the prominence they so well deserve.

In all cities there is great need of this grade of milk, and when its production is rightly managed, there is good opportunity for financial gain, as such milk will sell for from eight to twelve cents a quart. Milk of this character has been selling in Chicago for the past six years for twelve cents a quart.

THE CONSUMER'S RESPONSIBILITY.

That milk may reach the table in first-class condition, the consumer has responsibilities as well as the producer. The milkman is frequently blamed for many things for which he is not responsible. However perfect the condition and low the temperature of the milk when delivered, it cannot long remain in good condition unless carefully handled. If milk is to keep, it must be held at a low temperature, at least 60° F., and below if possible.

If milk is not delivered in bottles, care must be taken to protect it from dust, and it must be placed where there are no odors to be absorbed. Bottled milk, being sealed with a pulp cap, cannot absorb odors, and should be left in the bottle until used, not emptied into an open dish. If the cream is to be used first, that can be poured off and the cap replaced, thus protecting the milk left in the bottle. If it is desired to incorporate the cream with the milk, this can easily be done by turning the bottle end over end a few times, holding the finger on the cap to prevent its being pushed out. The milk needed can then be removed and the cap replaced.

IMPROVING CONDITIONS.

"Certified" milk should be the only standard, and it points the direction for improvement over the common methods of milk production. Most of the conditions for the production of certified milk are not expensive. With the majority of dairymen, only a few call for the outlay of additional money. The most important conditions, those involving cleanliness and safety, can be secured without appreciable expense. Here improvement can begin, and should begin at once, and go forward as rapidly as possible until all milk offered for direct consumption is produced according to the standard for certified milk.

Among the reforms that can be secured at insignificant expense, and which should be universally insisted upon, are the following:

To keep the cows clean, and not compel or allow them to wade and live in filth. This means clean yards and clean, well-bedded stalls. Everything short of this is positively repulsive and should not be tolerated any longer in a civilized community.

To stop the filthy practice known as "wetting the teats," by which is meant the drawing of a little milk into the hands with which to wet the teats before and during milking, leaving the excess of filthy milk to drop from the hands and teats into the pail.

To wash all utensils *clean* by first using lukewarm water, afterwards washing in warm water, and rinsing in an abundance of boiling water, then exposing until the next using in direct sunlight, which is a good sterilizer.

To use milk pails, cans, etc., for *no other purpose* but to hold milk.

To keep out of these utensils all sour or tainted milk, even *after* they have been used for the day. Using them for this purpose at any time infects them so badly that no amount of washing is likely to clean them. Bacteria are invisible, and millions can find lodging place in the thin film of moisture that remains after dishes are *apparently* clean.

To brush down the cobwebs and keep the barn free from accumulations of dust and trash.

To whitewash the barn at least once a year.

If these changes can be brought about, they will secure a comparatively clean product, and the improvement will amount almost to a reformation in the milk producing business. These changes involve but insignificant expense, either in money or labor, and there is no rational reason why they should not be made without delay, voluntarily, if possible, by compulsion if necessary.

When the dairy and surroundings are in the best shape possible for the present, a statement should be made as to the conditions under which the milk is produced, not claiming more than is actually carried out each day. By gradually raising his standard the industrious dairyman may, in time, work up to the grade known as certified milk.

Improving city milk supply is a matter of educating the public to demand better milk, and when the advantages of high grade milk are fully appreciated, people will be willing to pay the extra cost of production. The consuming public and the better class of dairymen are alike interested in bringing about these improvements with as little delay as possible.

NEED OF INSPECTION.

There are, and doubtless always will be, certain men producing milk who, from the slovenly methods they practice, are a disgrace to the dairy business. Such laws should be enacted, and such a system of inspection instituted, as will compel these men to be decent in their practices in handling milk or quit the business. It is time the dairymen moved in this matter and asked for inspection. If they do not, the public will soon do so, and when such matters are taken in hand by those who do not have the necessary technical information on the subject, the business may be injured and injustice done to honest dairymen who are putting out a good grade of milk.

UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION
URBANA, ILLINOIS

CIRCULAR No. 73

Milk Production

AT THE

University of Illinois

By
WILBER J. FRASER
Chief in Dairy Husbandry



Explanatory Note—This circular was originally issued to acquaint the local public with the methods employed at the University dairy. It is reprinted in connection with Circular No. 78 to familiarize milk consumers with the proper methods to be employed in the production of clean milk.

THE HERD

Choice specimens of Holstein-Friesians, Jerseys, Guernseys, and Ayrshires, with a few selected grades, comprise the University herd, which, bred to the best sires obtainable, is maintained as a breeding herd of a high order of excellence.

The health of the animals is kept constantly in view. They are frequently inspected by the professor of veterinary science, and are occasionally tested for tuberculosis, thus making the milk safe for infant use, without being either pasteurized or sterilized.

In summer a shady pasture, in winter a clean, comfortable barn, and exercise in a hard, well graded yard sheltered from the cold wind, always with selected feed and the purest water, insure the most perfect conditions known for the production of wholesome milk.



IN PASTURES GREEN.
Pure air is a good tonic.

THE BARN

The barn is capacious and provided with the King system of ventilation, which insures a constant supply of fresh air without causing a draft on the cows.

It is well lighted on all sides, and so arranged as to secure the sanitary requirements, and the quiet so essential for dairy cows. The stalls and mangers are roomy, and constructed with special regard to the comfort and cleanliness of the animal. All inside construction is made of dressed lumber, iron, and cement, and thus is easily kept clean.

The cows are well bedded with clean straw frequently renewed, and the floors and gutters are scrubbed each day. No dirt or filth is allowed to accumulate, and every precaution is taken against dust and bad odors at milking-time.



WAITING FOR THE MILKING HOUR.
The cow is a mother; treat her well.

MILKING

We have found by experimentation at the University that most of the filth and bacteria that find their way into milk come from the surface of the udder during the milking process. To prevent this contamination, the loose dirt is brushed from the sides and bellies of the cows, the udders are washed and wiped, and the milkers are required to cleanse their hands and put on clean white suits and caps.

The first milk drawn is rejected, as it contains many bacteria, which have developed in the milk at the orifice of the teats since the last milking.

As soon as drawn the milk is removed to the milk-room and either separated or cooled at once.



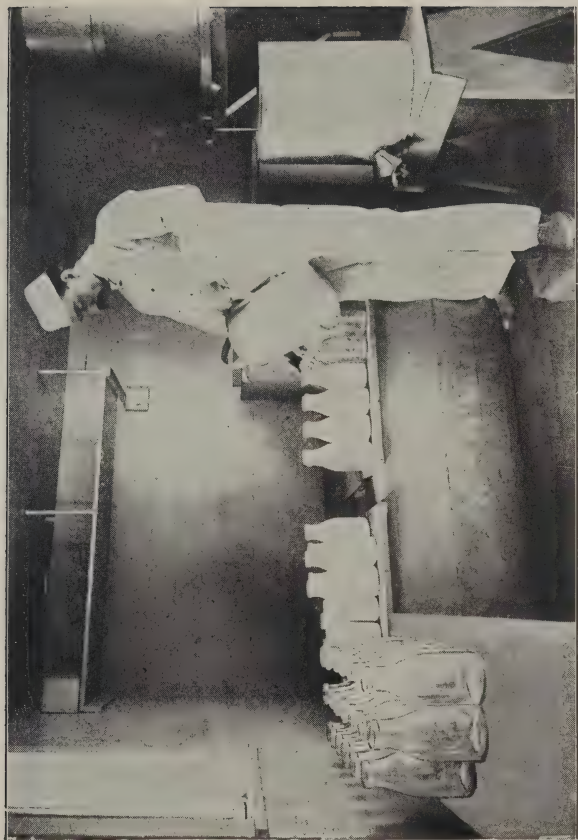
WASHING UDDERS BEFORE MILKING.
To secure the milk without contamination, that is the problem.

BOTTLING

From the cooler the milk all runs directly into one receiving vat, where it is thoroughly mixed when the milking is completed. Enough cream or skim milk is then added to bring the butterfat to four percent.

Because of the constant uniformity of this milk, it is much better for infant-feeding than the milk from a single cow, as the milk from one cow frequently varies greatly from milking to milking.

After the milk is standardized it is put into sterilized bottles and immediately sealed with paraffin pulp caps to protect it from contamination. It is then placed in the refrigerator and held below forty degrees Fahrenheit until delivered.



AERATING, COOLING, AND BOTTLING.
It is half in preparation.

SEPARATING AND STANDARDIZING

Cream is quickly obtained by passing milk through a centrifugal separator that has a speed of seven thousand revolutions per minute, and that may be adjusted to produce any desired richness. By this process the cream is secured before it commences to sour, and as it is immediately cooled it makes a product of excellent keeping quality.

The cream is frequently examined with the Babcock test, and by the adjustment of the separator the fat is kept at twenty-five per cent, which is the University standard for cream. The milk also is frequently tested, and held to the standard by adding sufficient skim milk or cream to bring the fat to four percent.

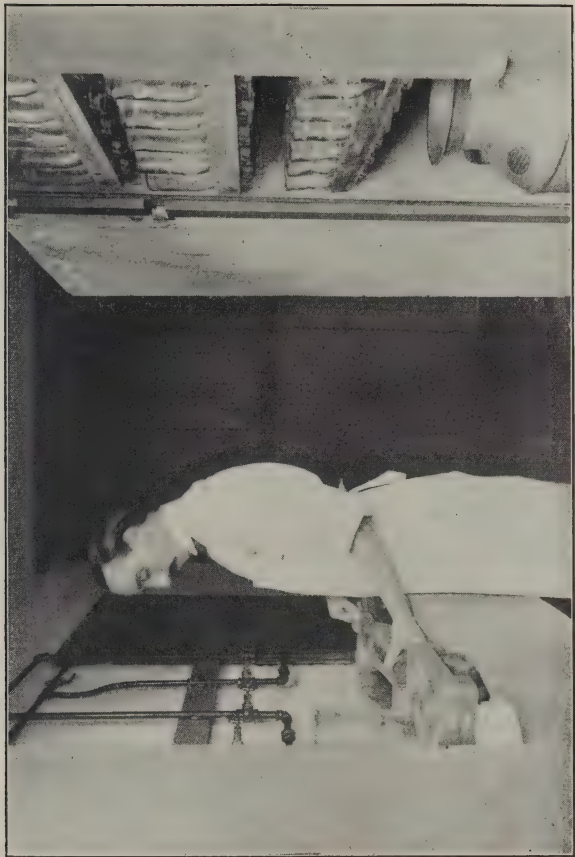


SEPARATING AND STANDARDIZING.
"Quality Guaranteed" is the best trade-mark.

UTENSILS AND DAIRY ROOMS

The pails, strainer, cooler, bottles, and everything with which the milk comes in contact are first rinsed in cool water, then thoroughly washed in hot water and soda, again rinsed, and afterwards sterilized for twenty minutes with live steam in a brick sterilizer. They are then both clean and sterile, and do not infect the milk.

The dairy is kept scrupulously clean, and is at all times free from dust and bad odors. The surroundings are favorable for pure air, and nothing producing bad odors is allowed to accumulate. Every effort is made to produce a milk that is as nearly free from all impurities and contamination as can be secured by most carefully observing all the principles and facts known to the science of dairying.



WASHING AND STERILIZING.
"Cleanliness is next to godliness."

DELIVERY AND GUARANTEE

Preparatory to delivery, the bottled milk is placed in zinc-lined wooden boxes, thus keeping it both clean and cool. In hot weather chipped ice is packed about the bottles to preserve their low temperature until they reach the consumers. Bottling not only prevents contamination during delivery, but also insures to all correct measure and uniform richness.

Milk and cream are delivered in bottles bearing the University name, and the contents are guaranteed to standard and to be produced as above described. Milk is sold at seven and a quarter cents a quart, and cream at seventeen and a half cents a pint.

Inspection is invited, and visitors are always welcome except on Sunday.



STARTING ON THE MORNING ROUNDS.
Appearance adds a flavor to the food.



UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

BULLETIN NO. 93.

SOIL TREATMENT FOR PEATY SWAMP LANDS, INCLUDING REFERENCE TO SAND AND "ALKALI" SOILS.

By CYRIL G. HOPKINS.



URBANA, ILLINOIS, JANUARY, 1904.

SUMMARY OF BULLETIN No. 93.

1. There are many thousand acres of peaty swamp land in northern Illinois, much of which produces almost no crops because the soil is deficient in the element potassium, although it is rich in all other elements of plant food. Page 275.

2. On the University of Illinois soil experiment field near Tampico (Whiteside County), on peaty swamp soil, the addition of potassium produced yields of 36 to 60 bushels of corn in 1902, and 45 to 66 bushels in 1903, while, with no potassium applied, no ear corn was produced. Page 277.

3. On the University of Illinois soil experiment field near Momence (Kankakee County), on peaty swamp soil, potassium produced 20 to 32 bushels of corn in 1902, and 67 to 73 bushels in 1903, while without potassium the average yield was only 5 bushels. Page 282.

4. Some kinds of peaty swamp soil will improve with the right kind of cultivation, and finally become very productive soils, which will not require the continued use of potassium, while other kinds will probably always require potassium to be applied. Page 292.

5. Some kinds of peaty swamp soils after years of cultivation are found to resemble sand ridge soil, which is most deficient in the element nitrogen, which can be obtained from the air at very slight cost by means of suitable leguminous crops. Page 294.

6. Nitrogen applied to the University of Illinois soil experiment field, near Green Valley (Tazewell County), on sand ridge soil, has increased the yield of corn from about 30 bushels to more than 60 bushels per acre. Page 295.

7. This bulletin tells how and where to purchase potassium, how to use it, and how to save it so that most of it can be used again and again for several crops. Page 297.

8. Certain kinds of farm manure produce fairly good results on some peaty swamp soils, but commonly it is better farm practice to use the manure on other kinds of soil and buy potassium for the peaty swamp soils. Page 298.

9. There is no more profit in starving plants than there is in starving animals. While heavy applications of potassium must sometimes be made at first, with proper management only light applications will be required after a few years. Page 299.

10. Farmers who have tried potassium in 1903 on peaty swamp lands report an increase of more than 30 bushels of corn, this increase being due to potassium. Page 300.

11. The so-called "alkali" soils of Illinois, which are also being investigated, are not the same as peaty swamp soils. Page 301.

12. The Experiment Station cannot undertake to analyze miscellaneous samples of soil for private parties. Methods of soil investigation must be systematic and exact. Page 302.

13. Upon request to the Illinois Experiment Station, Urbana, Ill., this bulletin will be sent to any one interested in Illinois agriculture.

SOIL TREATMENT FOR PEATY SWAMP LANDS, INCLUDING REFERENCE TO SAND AND "ALKALI" SOILS.

BY CYRIL G. HOPKINS, CHIEF IN AGRONOMY AND CHEMISTRY.

There are immense areas of peaty swamp lands in the northern and north-central part of Illinois. As a rule these soils do not grow good crops. When first broken, they sometimes yield one or two fair crops of corn, but generally the third crop is very poor, and afterward little or no corn is produced. Oats do somewhat better, but usually the yield of grain is very unsatisfactory, even when a fair amount of straw is grown. These soils are usually very black and very rich in organic matter, and they are frequently drained at great expense with the expectation that they will be very productive and almost inexhaustible, but not infrequently they yield disappointment and financial loss.

While it will not be possible to locate and investigate all of the different tracts of peaty soil until we extend the detail soil survey over the entire state, nevertheless we have already obtained considerable information regarding these lands in connection with our general survey of Illinois soils, and this bulletin is published because we know that this information can be used by many Illinois farmers and land-owners with advantage and profit in increasing the productive capacity of such soils.

These peaty swamp soils are present in large areas in Lee County, in southern Whiteside County, in Rock Island County, in the northeastern part of Henry County, and in the northwestern part of Bureau County. In Kankakee and Iroquois Counties, in northern Mason County, and southwestern Tazewell County, large tracts of peaty soil are found; and smaller tracts are found in the counties of Winnebago, Boone, McHenry, Lake, Dekalb, and Kane, and there is more or less of this soil in several other northern counties, such as Kendall, Will, LaSalle Grundy, Livingston, etc. Some peaty soil has been found in northern Ford County, and one small tract in western McLean County. This soil is also known to extend into northern Indiana* and southern Wisconsin,* and it is reported as present in Iowa to considerable extent.

Commonly the peaty soil occupies the lower lying areas, but sometimes it is found in table-lands. It is always on land which was at one time poorly drained.

The peaty soil varies from almost pure brown peat, containing 80

*The experiment stations of Indiana and Wisconsin have published some results of investigations relating to similar soils, and in several cases a deficiency of potassium has been strongly indicated. (See page 290.)

percent or more of combustible material, to black muck, containing much less organic matter. In some places these soils extend continuously over tracts of considerable size (sometimes over several square miles), to the exclusion of other types of soil; but more commonly the peaty soils occupy irregularly shaped areas scattered about in bodies of land of different kinds. Sandy land is frequently found adjoining or surrounding the tracts of peaty soil, and sand is the most common subsoil found under peaty swamp soils, although a clay subsoil is found in many places, and sometimes the peaty soil is underlain, at a depth of only a few feet, with limestone rock. Occasionally the peaty soil adjoins ordinary Illinois prairie land.

Peat itself consists largely of partially decayed sphagnum moss, which grew in the water which once covered these areas. In growing, the moss obtains carbon, from the carbon dioxide in the air, and hydrogen and oxygen, from water, being similar to other plants in this respect. The water in which the sphagnum moss grows is more or less stagnant. It is usually surface-drainage or seepage water, and contains sufficient nitrogen, phosphorus, potassium, and other essential elements of plant food to meet the needs of the growing moss. Both nitrogen and phosphorus enter into fairly stable organic combinations with the carbon, hydrogen, and oxygen, and when the moss changes to peat, and even when the peat partially decays, these two elements, nitrogen and phosphorus (especially the nitrogen), are largely retained in the organic matter. The potassium, however, reverts more largely to the soluble form and it is finally lost to a greater or less extent in the drainage waters flowing from the peat bogs.

A considerable number of the peaty swamp soils from different places in the state have been analyzed by the Experiment Station, and they are found to be very rich in nitrogen, well supplied with phosphorus, but very deficient in potassium, as compared with the ordinary fertile soils of the state. It has long been known that such soils are frequently deficient in mineral elements.

Some preliminary field tests made by the Experiment Station, and by farmers who were induced through correspondence with the Experiment Station to make some trials, gave results strongly indicating the need of applying available potassium to some of these soils. Pot culture experiments gave similar indications, and the field experiments which are reported* in this bulletin certainly furnish very conclusive proof of the power of potassium to increase the productive capacity of some of these soils.

In this connection the author desires to mention his appreciation of the assistance of Mr. J. E. Readhimer in superintending these field

*Some reference to these investigations has already been made in Circulars 64, 68, and 72. (See also previous foot-note.)

experiments, and also the value and importance of the care which has been given to these different soil experiment fields by the progressive and interested farmers upon whose farms the fields were located, as indicated in the following pages.

TAMPICO SOIL EXPERIMENT FIELD.

This is one of the regular University of Illinois soil experiment fields. It is located in the S. E. 40 of the S. W. $\frac{1}{4}$ of Sec. 6, Twp. 19 N., R. 7 E. of the 4th P. M., on the farm of Mr. J. H. Milligan, about five miles northeast of Tampico, Whiteside County, Illinois. The soil consists of black peaty material, rich in organic matter to a depth of sixteen inches. Between 16 and 30 inches the material is lighter in color and quite sandy, with little organic matter. The subsoil below 30 inches is almost pure coarse sand. This soil is fairly representative of considerable amounts of land in southern Whiteside and adjoining counties, which is non-productive, or of very low productive capacity, especially for corn.

This field consists of ten tenth-acre plots, numbered from 101 to 110. The individual plots are each two rods wide and eight rods long, each plot being surrounded by a cropped and cultivated border one-fourth rod wide, which makes one-half rod division strips between adjacent plots. The treatment applied to these different plots is what we call our "complete fertility test." It includes trials with applications of the elements, nitrogen, phosphorus, and potassium, singly, in all possible double combinations, and all three together, all in connection with lime; also a double test as to the effect of applying lime, first with lime alone, and finally with the three elements added. The plan will be easily understood by reference to the tabular statements. (L means lime, N means nitrogen, P means phosphorus, and K means potassium, from the Latin name *kalium*, this symbol (K) being used for potassium by all nations.)

Nitrogen is applied in the form of dried blood, a material containing 12 to 14 percent of nitrogen. About 800 pounds of dried blood per acre are used each year. This would furnish about 100 pounds of nitrogen or as much as is contained in 100 bushels of corn. Of course the nitrogen is purchased and applied in readily available commercial form in order to ascertain as quickly as possible if the soil is in need of nitrogen. If this were found to be the case it would simply indicate that in farm practice more nitrogen should be obtained from the air by means of leguminous crops, as we are doing in our rotation experiments (see Bulletin No. 88, "Soil Treatment for Wheat in Rotations"), and not that commercial nitrogen should be bought and applied to the soil (100 pounds of commercial nitrogen cost about \$15, while that quantity of nitrogen can be obtained from the air with clover and other legumes for about \$1).

The phosphorus is applied in steamed bone meal. This material

contains about $12\frac{1}{2}$ percent of the element phosphorus, and is one of the best forms of phosphorus to purchase when needed in general farming. About 200 pounds of steamed bone meal per acre are applied each year. This furnishes about 25 pounds of phosphorus, or more than is contained in a 100-bushel crop of corn, the grain containing about 17 pounds and the stalks 6 pounds of that element. Owing to the fact that the steamed bone meal is not completely available the first season, the first annual application is usually 400 instead of 200 pounds (phosphorus in steamed bone meal usually costs from 10 to 12 cents a pound, the steamed bone meal itself being \$25 to \$30 a ton).

Potassium is applied in the form of potassium chlorid (containing about 42 percent of potassium), or potassium sulfate (containing about 40 percent of that element). About 200 pounds of the salt are applied the first year, and 100 or 200 pounds per acre each year afterward. One hundred bushels of corn contain about 19 pounds of potassium, and the corresponding three tons of stalks contain about 52 pounds of that element. If the stalks or the ashes from the stalks are left on the land, well distributed, the annual loss in potassium is only about 20 pounds for a very large crop of corn, and 100 pounds of potassium chlorid will furnish 42 pounds of the element potassium. If both grain and stover are removed about 200 pounds must be added each year.

The results obtained from the Tampico soil experiment field in 1902 (the first year) are shown in Table 1. It should be stated that although lime was applied to certain plots in this field in the beginning of the experiment, in accordance with our regular plan of "complete fertility tests," it has produced no effect whatever, and the subsequent analysis of soil samples taken at the time the field was located also shows that the soil is not in need of lime. (Lime is not added as an element of plant food, but only to correct any possible acidity of the soil, and thus to insure good physical conditions where the elements of plant food are added.)

TABLE 1.—CROP YIELDS IN SOIL EXPERIMENTS; TAMPICO FIELD, 1902.

Soil plot No.	Soil treatment applied to peaty swamp soil.	Yields per acre.	
		Corn, bushels.	Stover, pounds.
101	None	0	1,000
102	Lime	0	800
103	Lime, nitrogen	0	1,200
104	Lime, phosphorus	0	2,000
105	Lime, potassium	36.3	3,600
106	Lime, nitrogen, phosphorus	0	1,400
107	Lime, nitrogen, potassium	40.0	3,500
108	Lime, phosphorus, potassium	37.5	3,100
109	Lime, nitrogen, phosphorus, potassium	60.0	4,400
110	Nitrogen, phosphorus, potassium	52.5	4,750

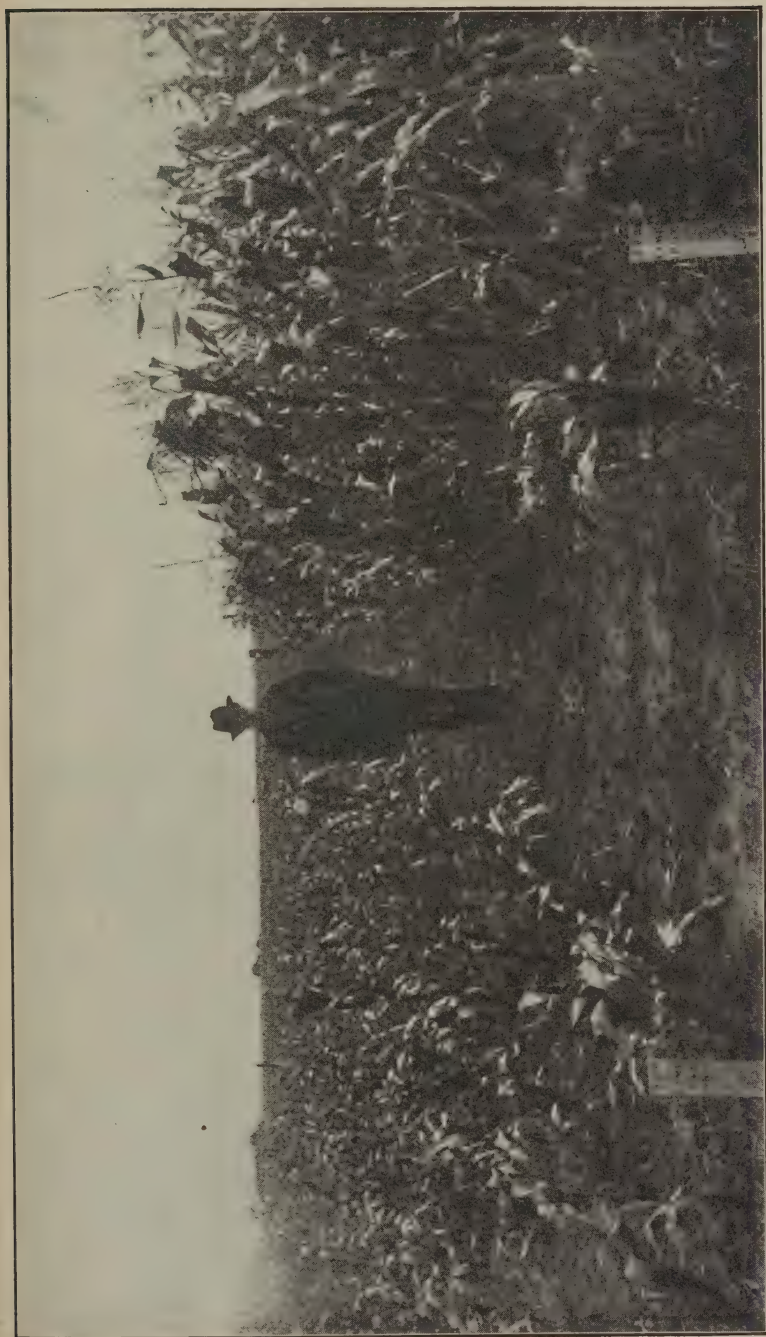


PLATE 1.—CORN ON PEATY SWAMP LAND, TAMPICO FIELD, 1902. NITROGEN AND PHOSPHORUS ON LEFT; POTASSIUM ON RIGHT.

It will be observed that every plot to which potassium was applied produced a fair crop of corn, varying from 36 to 60 bushels, while no ear corn was produced on any plot not treated with potassium. Even the yield of stover, or barren stalks, was small on plots not receiving potassium. There was considerable variation in the yield of corn from the plots treated with potassium. This was probably caused more by the excessive rainfall and consequent injury to some plots from too much water than from the effect of other applications beside potassium. Like much of these swamp lands, this field was not sufficiently well drained to protect it in excessively wet seasons. Plot 109 is slightly higher than most of the other plots, and this is believed to account largely for the higher yield on that plot.

Plate 1 shows the corn growing on Plot 106 with nitrogen and phosphorus, on the left, and on Plot 105 with potassium, on the right.

Table 2 shows the results obtained from this same field in 1903 (the second year).

TABLE 2.—CROP YIELDS IN SOIL EXPERIMENTS; TAMPICO FIELD, 1903.

Soil plot No.	Soil treatment applied to peaty swamp soil.	Yields per acre.			
		Corn, bushels.			Stover, pounds average.
		N. $\frac{1}{2}$ plot.	S. $\frac{1}{2}$ plot.	Average.	
101	None	0	0	0	570
102	Lime	0	0	0	590
103	Lime, nitrogen	0	0	0	480
104	Lime, phosphorus	0	0	0	740
105	Lime, potassium	42.3	48.5	45.4	4,150
106	Lime, nitrogen, phosphorus.....	0	0	0	600
107	Lime, nitrogen, potassium	57.6	59.7	58.7	4,170
108	Lime, phosphorus, potassium	47.1	46.6	46.9	3,860
109	Lime, nitrogen, phosphorus, potassium	66.3	65.4	65.9	4,380
110	Nitrogen, phosphorus, potassium	53.2	64.0	58.6	3,960

The five plots receiving potassium produced from 45 to 65 bushels of corn per acre, while no ear corn was produced on any of the five plots to which no potassium was applied. Owing to the very wet season of 1903, the yields from most of the plots receiving potassium are lower than they would otherwise have been, Plot 109 being the highest, as in 1902, and largely for the reason previously given. It is evident that the excessive amount of water in the soil retarded the nitrification of the organic nitrogen naturally contained in the soil in very large amounts; while the nitrogen supplied in the form of dried blood, being in the surface soil and very easily nitrified, did effect some increase in the yield wherever both potassium and nitrogen were added. This effect was

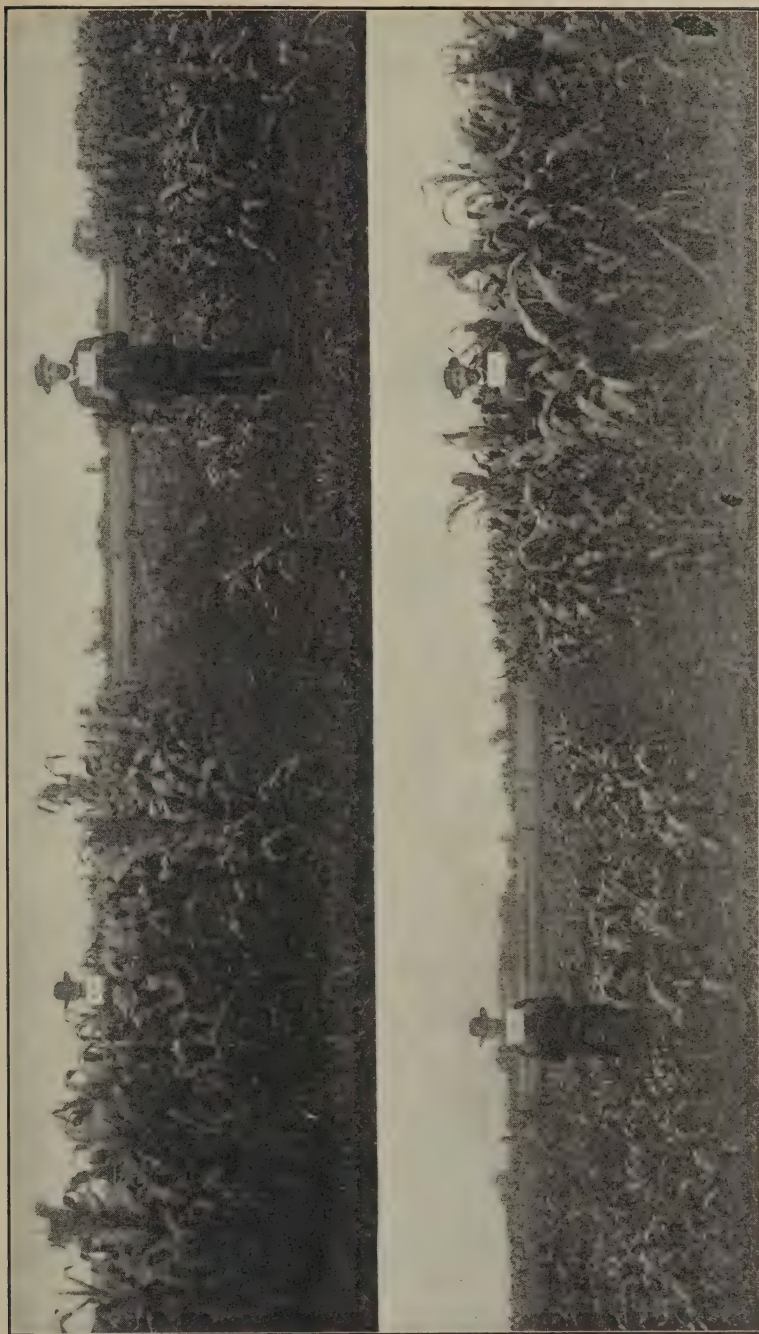


PLATE 2.—CORN ON PEATY SWAMP LAND, TAMPICO FIELD, 1903. UPPER VIEW: POTASSIUM ON LEFT, WITH NITROGEN AND PHOSPHORUS ON RIGHT. LOWER VIEW: NITROGEN AND PHOSPHORUS ON LEFT, WITH NITROGEN AND POTASSIUM ON RIGHT.

plainly apparent during the growing season, the stronger growth and darker color of the plants treated with nitrogen in connection with potassium being distinctly discernible. Of course this result does not indicate that commercial nitrogen could be used with profit on this soil, but rather that the field needs better drainage in such wet seasons. (This is being arranged for.) This soil is naturally several times richer in nitrogen than the most fertile soils in the corn-belt. It is also well supplied with phosphorus. With more perfect drainage and a plentiful supply of potassium, this soil is undoubtedly capable of producing even more than 65 bushels of corn to the acre. (See results obtained from the Momence field.)

Plate 2 shows the 1903 crop growing on the Tampico field. The upper view shows Plot 5 (**potassium**) on the left, and Plot 6 (nitrogen and phosphorus) on the right. The lower view shows Plot 6 (nitrogen and phosphorus) on the left, and Plot 7 (nitrogen and **potassium**) on the right. (As stated above, this soil naturally contains abundance of lime, a small amount of which was added to these plots in the beginning of the experiment before the soil had been analyzed, not as plant food, but only to insure good physical condition. The lime was not needed, however, and it has produced no effect.)

MOMENCE SOIL EXPERIMENT FIELD.

This is also one of the regular University of Illinois soil experiment fields. It is located in the N. E. 40 of S. E. $\frac{1}{4}$ of Sec. 6, Twp. 30 N., R. 11 W. of 2nd P. M., on the farm of Mr. C. C. Porter, about three miles south of Momence, Kankakee County, Illinois, on peaty swamp soil which is underlain with impure limestone at a depth of two to three feet, with about 12 inches of yellow sandy subsoil between the black soil and the underlying rock.

A considerable part of the north half of plots 101 and 102 and a smaller part of the other plots extend over somewhat different land where the soil contains sufficient available potassium to produce a medium crop of corn in a good season.* The south halves of the plots are on soil which is fairly representative of the most non-productive phase of this peaty swamp soil. There are very large areas of swamp soil in Kankakee and adjoining counties of very low productive capacity, much of which will probably respond to the same treatment as this field. (There are some probable exceptions, however, which will be noted below.)

The Momence field is laid out in the same manner and receives the same kinds of treatment as the Tampico field. Table 3 shows the results which were obtained in 1902.

*In locating our soil experiment fields, we endeavor to select as uniform land as possible, but if there is any apparent difference in the field we always try to put the check plot with no treatment on the best soil in order that the effect of the treatment shall not be exaggerated.

TABLE 3.—CROP YIELDS IN SOIL EXPERIMENTS; MOMENCE FIELD, 1902.

Soil plot No.	Soil treatment applied to peaty swamp soil.	Yields per acre.	
		Corn, bushels.	Stover, pounds.
101	None	6.9	940
102	Lime	5.5	820
103	Lime, nitrogen	0	560
104	Lime, phosphorus	1.3	500
105	Lime, potassium	23.7	2,720
106	Lime, nitrogen, phosphorus	0	500
107	Lime, nitrogen, potassium	19.7	2,420
108	Lime, phosphorus, potassium	32.0	2,940
109	Lime, nitrogen, phosphorus, potassium	25.2	2,480
110	Nitrogen, phosphorus, potassium	24.1	2,460

The crop was injured very considerably during the wet season of 1902, because of inadequate drainage, a condition which was corrected before the 1903 crop was grown on this field. Nevertheless the effect of potassium on the 1902 corn crop is very marked. Aside from the ends of the plots which occupied somewhat higher ground, capable of producing a medium crop, the five plots receiving no potassium produced practically no ear corn, while the five plots treated with potassium yielded 20 bushels or more of corn per acre. Marked increase in the yield of stover also follows the application of potassium.

Although the season of 1903 was also one of abundant rainfall, the Momence field had been provided with sufficient drainage to prevent serious injury from water as will be seen from the results which are given in Table 4.

TABLE 4.—CROP YIELDS IN SOIL EXPERIMENTS; MOMENCE FIELD, 1903.

Soil plot No.	Soil treatment applied to peaty swamp soil.	Yields per acre.			
		Corn, bushels.			Stover, pounds average.
		N. $\frac{1}{2}$ plot.	S. $\frac{1}{2}$ plot.	Average.	
101	None	29.7	0	14.9	1,080
102	Lime	14.2	0	7.1	820
103	Lime, nitrogen	7.2	0	3.6	750
104	Lime, phosphorus	9.2	0	4.6	1,040
105	Lime, potassium	72.0	72.5	72.6	3,770
106	Lime, nitrogen, phosphorus	7.7	0	3.9	730
107	Lime, nitrogen, potassium	79.2	63.0	71.1	3,160
108	Lime, phosphorus, potassium	78.2	68.0	73.1	3,380
109	Lime, nitrogen, phosphorus, potassium	71.5	62.0	66.7	3,010
110	Nitrogen, phosphorus, potassium	77.7	63.0	70.4	3,230

These results are certainly exceedingly marked as to the effect of potassium in this soil. On the south halves of the plots, on the most non-productive soil, no ear corn was produced on any of the five plots receiving no potassium, while the five plots treated with potassium produced from 62 to 72 bushels of good sound corn per acre. On the north halves the potassium increased the yield from less than ten bushels to more than 70 bushels per acre. (The north ends of plots 101 and 102 are not fairly comparable with the remaining plots, as will be plainly seen from the yields produced. This will be understood from the previously given explanation.)

It is very evident that potassium is the only element of plant food needed to change this almost barren soil to one of the most productive soils in the corn belt.

Plates 3, 4, and 5 show the crops growing on the Momence field in 1903. Plates 3 and 4 show Plots 1, 2, 3, 4, and 5, in the order given.

The upper view in Plate 3 shows Plot 1, to which no treatment was applied. On the right, looking over Plots 2, 3, and 4, we see Plot 5, to which potassium was applied.

The lower view in Plate 3 shows Plot 2, to which lime only was applied. On the right we see the good corn in Plot 5, beyond plots 3 and 4.

The upper view in Plate 4 shows Plot 3, to which nitrogen was applied, on the right of which is Plot 4, with Plot 5 beyond.

The lower view of Plate 4 shows Plot 4 (phosphorus) on the left, and Plot 5 (**potassium**) on the right, where the corn yielded 72 bushels to the acre.

The upper view of Plate 5 shows Plot 5 (**potassium**) on the left, Plot 6 (nitrogen and phosphorus) in the middle, and Plot 7 (nitrogen and **potassium**) on the right. Potassium on Plot 5 made 72 bushels, and on Plot 7 potassium with nitrogen made 71 bushels of good sound corn (80 pounds per bushel), while Plot 6 between those two made less than 4 bushels of nubbins.

The lower view in Plate 5 shows the effect of potassium on buckwheat on the Momence field, potassium having been applied on the right, and nothing applied on the left.



PLATE 3.—CORN ON PEATY SWAMP LAND, MOMENCE FIELD, 1903. UPPER VIEW: NO TREATMENT. LOWER VIEW: LIME TREATMENT.

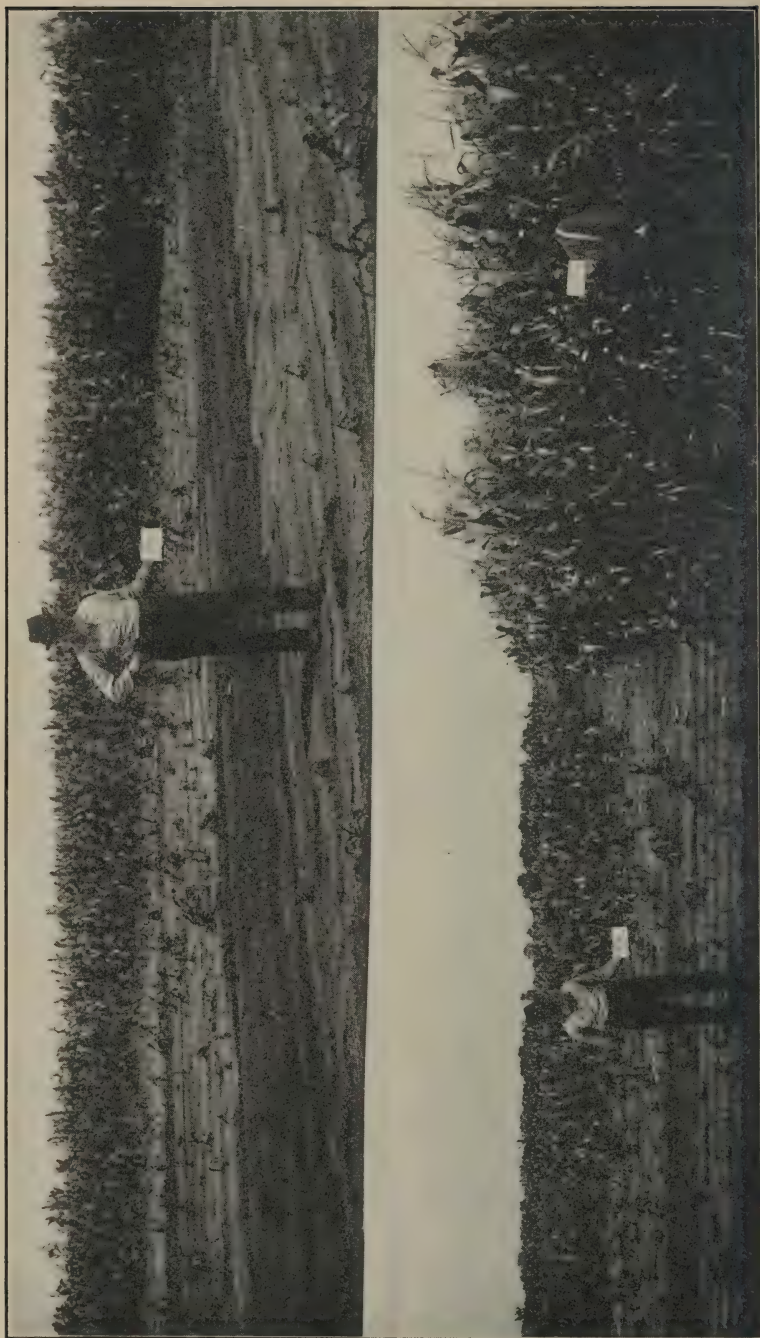


PLATE 4.—CORN ON PEATY SWAMP LAND, MOMENCE FIELD, 1903. UPPER VIEW: NITROGEN. LOWER VIEW: PHOSPHORUS ON LEFT, POTASSIUM ON RIGHT.

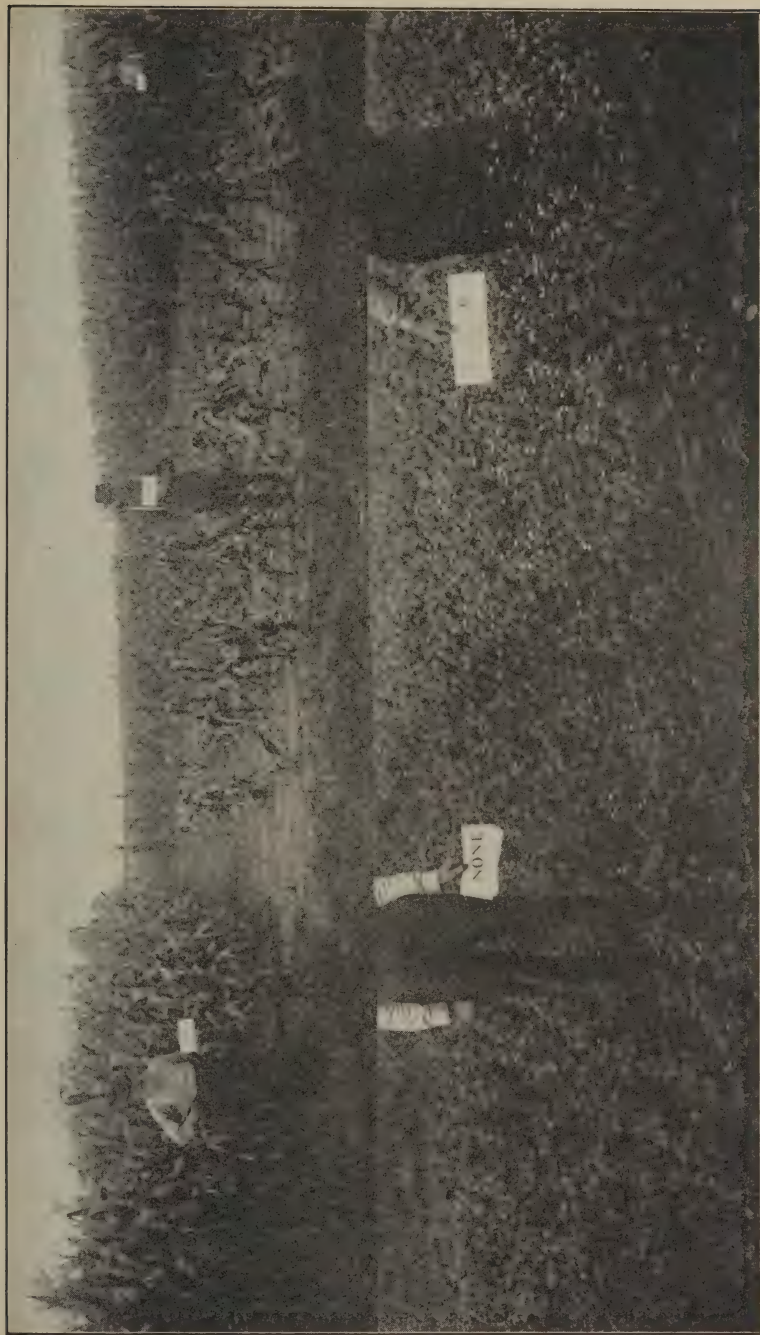


PLATE 5.—CORN AND BUCKWHEAT ON PEATY SWAMP LAND, MOVENCE FIELD, 1903. EFFECT OF POTASSIUM. "SEE HIS FEET!"
(APOLOGIES TO MESSRS. PORTER AND SONS.)

MANITO SOIL EXPERIMENT FIELD.

This is a co-operative soil experiment field, located on peaty swamp soil about one mile northeast of Manito, in Mason County, Illinois, almost on the line between Mason and Tazewell counties. It is on the farm of Mr. James S. Pollard, which is operated by Mr. Joseph Brenner. The soil is a black peaty material, consisting largely of organic matter. It is quite uniform to a depth of several feet. At a depth of six or eight feet (in places twelve to fifteen feet), the peaty material is underlain with sand. The Manito experiment field contains ten one-acre plots. The treatment indicated in Table 5 was applied for the 1902 crop only, no subsequent applications having been made, although crops of corn for the two years, 1902 and 1903, have been harvested, the yields of corn obtained being also given in the table.

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS; MANITO FIELD, 1902 AND 1903.

Soil plot No.	Soil treatment applied to peaty swamp soil. (Amounts per acre.)	Corn, bushels per acre	
		1902.	1903.
1	None	10.9	8.1
2	None	10.4	10.3
3	600 lb. Kainit (10% potassium)	30.4	32.3
4	600 lb. Kainit and 350 lb. bone meal	30.3	33.3
5	200 lb. potassium chlorid (42% K)	31.2	33.7
6	700 lb. common salt	11.1	11.6
7	700 lb. common salt	13.3	13.2
8	600 lb. Kainit (10% K)	36.8	37.3
9	300 lb. Kainit (10% K)	26.4	25.5
10	None	No report	14.7

A large open ditch provides fairly good drainage for the swamp in which the Manito field is located, but the excessive rainfall of 1902 certainly injured the yield to a considerable extent. The fact that no further application of potassium was made for the second crop probably accounts for the comparatively low yield of 1903. The effect of potassium on this field has been to increase the yield of corn from about 10 bushels to more than 30 bushels per acre. Phosphorus (in bone meal) applied in addition to potassium (Plot 4), produced no increase over potassium alone. The results are practically the same whether the potassium is applied in the form of potassium chlorid, containing 42 percent of potassium, or as kainit, a crude mineral containing only 10 percent of potassium. Although the application of 600 pounds of kainit is not quite equivalent to 200 pounds of potassium chlorid, the kainit has given nearly as good results during the two years' trials. The cost of 600 pounds of kainit is about the same as 200 pounds of potassium chlorid. Of course it is somewhat more expensive to handle the heavier amounts of kainit, and

the fact that 200 pounds of potassium chlorid contain 84 pounds of potassium, while the 600 pounds of kainit contain only 60 pounds of potassium, is evidence that the effect of the potassium chlorid will be more lasting. Where the application of potassium was reduced from 60 pounds (in 600 pounds of kainit) to 30 pounds (in 300 pounds of kainit) the yield of corn was reduced from 36 to 26 bushels in 1902, and from 37 to 25 bushels in 1903. (See Plots 8 and 9.) It seems altogether probable that heavier applications of potassium (say 200 pounds of potassium chlorid each year) will increase the yield of corn on this soil to 60 or 70 bushels, or possibly more, as has been the result on the Momence field. This is to be tried on the Manito field.

It should be borne in mind that the stalks for a hundred-bushel crop of corn require 52 pounds of potassium (beside that required for the root growth), while the 100 bushels of grain will require 19 pounds. Of course the stalks must be grown before the ears can be produced; and, while there is a strong natural tendency in corn, as in all plants, to reproduce seed, yet it has been shown by actual trial that in such soil as that on the Tampico field, for example, which, without treatment, is incapable of producing ear corn, small applications of potassium are practically useless, as they only effect a larger growth of stalks, but do not furnish sufficient potassium to enable those stalks to produce ears. This fact was well illustrated on Mr. Milligan's land adjoining the Tampico field in 1903. Because of the marked results produced by potassium on that field in 1902, Mr. Milligan used some potassium on his own corn for 1903. The amount of potassium chlorid which he purchased was not sufficient to make a heavy application (say 200 pounds per acre) to all of the land where he wished to apply it. He reduced the application to 50 pounds of potassium chlorid per acre on some of his land. As a result he obtained a largely increased growth of stalks, but still produced practically no ear corn. On such land, 200 pounds of potassium chlorid is worth very much more when applied to one acre than when scattered over four acres.

The results obtained on Plots 6 and 7 of the Manito field prove conclusively that common salt (sodium chlorid) has no power to take the place of potassium chlorid (or other potassium salts) in the improvement of these peaty swamp soils. Plots 1, 2, 6, 7, and 10, may all be considered as check plots. From the yields obtained from these plots during the two years, it will be seen that there is some natural variation in the land, the yield increasing somewhat as we pass from Plot 1 to Plot 10. Plots 3 and 8 also illustrate this fact.

Owing to the more favorable season of 1903 (less injury from water) larger yields were produced in 1903 than in 1902 on the plots treated with potassium, although no additional potassium was applied for the 1903 crop. The one exception to this rule is plot 9, which received only

30 pounds of potassium per acre, of which too little remained for the 1903 crop to produce as good a yield as in 1902, even though the water conditions were more favorable in 1903.

RESULTS OF INVESTIGATIONS IN INDIANA AND WISCONSIN.

As previously stated the Indiana and Wisconsin experiment stations have reported some investigations of non-productive soils, including some peaty swamp soils.

Bulletin No. 57 of the Indiana Agricultural Experiment Station on "The Improvement of Unproductive Black Soils," by Professor H. A. Huston, published in 1895, contains the following general conclusions:

"The use of straw or kainit has proved very profitable as a means of *temporary* improvement of such lands.

"The *permanent* improvement of such lands must be effected by efficient drainage."

In the summary of Bulletin No. 95 of the Indiana Station, which was published in 1903, and which is essentially a reprint of Bulletin No. 57, Professor Huston inserts the following additional conclusion:

"On black lands containing considerable sand but not having a high water level, kainit and other potash salts have proved very profitable fertilizers for corn."

Bulletin No. 80 of the Wisconsin Agricultural Experiment Station on "The Character and Treatment of Swamp or Humus Soil," by Professor F. H. King and J. A. Jeffrey, published in 1900, contains the following conclusions:

"So far as the elements of plant food are concerned [these soils] contain a higher percent than most of the best upland soils.

"But when reclaimed they are often found relatively unproductive, especially after two or three years.

"Coarse farmyard manure, in almost all cases, greatly improves even the best of these lands, enabling them to give large yields.

"Potassium carbonate, sulfate, and nitrate, and wood ashes have been found to greatly improve these soils for corn. Kainit improves the yield, but to a less degree.

"Coarse litter, like straw, plowed in, is often very helpful.

"When undrained and kept in the native wild grass and cut continuously, these lands in some known cases greatly decrease in productiveness, so much so as to hardly pay for cutting."

It is evident that in the investigations above summarized no very clear distinction is made between the very peaty swamp soils which are exceedingly deficient in the element potassium as compared with normal fertile soils, and the non-productive "alkali" or "bogus" soils, which are usually rich in all elements of plant food, including potassium. These different classes of non-productive soils are discussed in the following pages.

PLANT FOOD IN DIFFERENT SOILS.*

It is true that plants are composed very largely of the elements carbon, hydrogen, and oxygen, that carbon is obtained from the inexhaustible supply of carbon dioxid in the air, and hydrogen and oxygen are the elements of which water is formed. It is also true that plants must be supplied with the elements calcium, magnesium, sulfur, and iron, but these four elements are required by plants in relatively small amounts, and practically all soils are abundantly supplied with them. The other three elements of plant food, nitrogen, phosphorus, and potassium, are required by plants in very considerable amounts, and they are present in most soils in limited quantities.

Nitrogen is a constituent of organic matter, consequently, if a soil is rich in organic matter (humus or vegetable matter), it is also rich in nitrogen; and if a soil is poor in organic matter, it is also poor in nitrogen. If more nitrogen is needed it can best be obtained by growing leguminous crops, provided with the proper nitrogen-gathering bacteria, which have power to obtain nitrogen from the air.

Phosphorus is also associated with organic matter to some extent, so that a soil *very* rich in organic matter (as peaty soils) is not only exceedingly rich in nitrogen, but it is usually well supplied with phosphorus. In the light-colored timber soils, and in worn prairie soils, especially those of southern Illinois, phosphorus is more or less deficient in the soil. It can be supplied very profitably in steamed bone meal, and probably in ground rock phosphate, also; but, as a rule, it should be used only in connection with leguminous crops or farm manure.

Potassium is commonly associated with clay, that is, the true sticky, plastic clay. It is contained in all ordinary Illinois soils, as the common prairie soils, in great abundance (southern Illinois soils have only a moderate supply). Peaty soils not mixed with sticky clay are, as a rule, very deficient in potassium. Sand soils also are usually poor in potassium. Sand soils are likewise commonly deficient in the other elements of plant food, especially in nitrogen. (Absolutely pure sand contains no plant food whatever.)

With these facts in mind, it is possible for the farmer to estimate with some degree of accuracy what will be required to increase the productive capacity of the different kinds of peaty swamp soils, and whether the treatment must be continued indefinitely, year after year, or whether the soil is likely to improve, or "farm out," after a few years.

*For more complete information regarding the different elements of plant food, the reader is referred to Circular No. 68, "Methods of Maintaining the Productive Capacity of Illinois Soils," a copy of which will be sent upon request to any one interested in Illinois agriculture.

GENERAL INFORMATION REGARDING PEATY SWAMP SOILS.

Peaty swamp soils may well be separated arbitrarily into five fairly distinct classes:

1. Soils in which the very peaty material extends to a depth of three or four feet at least and often to much greater depths.
2. Soils with one to three feet of peaty material resting on deep sand.
3. Soils with one to three feet of peaty material resting on rock, usually with some inches of sandy material between the two.
4. Soils with six inches to three feet of peaty material resting on a clayey subsoil.
5. Soils with only a few inches of peaty material resting on sand.

If the soil has one to three feet of very peaty material and this is underlain with a deep sand subsoil or with sand resting on rock, or if the peaty soil itself is very deep (3 or 4 feet or more), then the land is almost certainly deficient in potassium, and the chief part of the potassium required to produce crops must always be supplied, either in the form of commercial potassium salts or in farm manure, because of the simple fact that it cannot be furnished by either the soil or subsoil in sufficient quantities for continuous large crops. As the one to three feet of peaty material is exceedingly rich in organic matter, and is much richer in nitrogen, and usually somewhat better supplied with phosphorus, than the most fertile normal soils in the corn-belt, that land is not in need of either of those elements, and probably it will be unnecessary to grow clover or to apply phosphorus on such soils for many years. Indeed, it seems altogether likely that the most profitable system of farming for such soils is almost continuous corn, unless some rotation should become necessary because of corn insects. As farm manure contains about as much nitrogen as potassium, and also some phosphorus, it is better farm practice to use farm manure on sandy land, for example, which is usually somewhat deficient in both phosphorus and potassium, and very greatly in need of nitrogen and organic matter, than it is to use the manure on this peaty soil which needs only potassium. Ordinary farm manure contains about 10 pounds of potassium in a ton, and this is not very readily available, excepting in such kinds as horse manure which decompose quickly.

If one has abundance of farm manure, and does not need to use it all on lighter soils, of course, it should be applied to the peaty soils rather than not be used at all; but under the ordinary farm conditions, where the supply of farm manure is very limited, it is good practice to purchase commercial potassium for such peaty lands as need it.

As stated above, there are some peaty soils which are underlain with clay subsoils lying from 6 inches to three feet below the surface. Such

subsoils almost invariably contain abundance of potassium. Some of these are the soils which will ultimately "farm out," to use a local phrase, which means that with continued farming the soil gradually improves until it finally becomes a normally fertile soil, even without any special treatment. The time required for this improvement will depend upon the condition and method of management of the soil. The desired result is usually accomplished by getting some of the clayey subsoil mixed with the more peaty top soil. Sometimes this can be done by deeper plowing; sometimes by the tramping of live stock, where the subsoil is near the surface. Some soils of this class are temporarily benefited very markedly by even light applications of potassium, either in farm manure (preferably horse manure) or in commercial form. This will furnish sufficient potassium to give the corn a start, and the corn roots will thus be enabled to grow sufficiently to reach the clayey subsoil which will then furnish abundance of potassium for a large crop. This may last for a year or two only, when it will be found necessary to supply more potassium to the top soil; or, the one or two years' cropping and cultivation may result in the compacting of the surface soil, the mixing of the clayey subsoil with the peaty top soil, or the bringing up of sufficient potassium from the subsoil into the top soil by the roots of corn and weeds and the corn-stalks (which, it will be remembered, are quite rich in potassium, and which are usually either burned or plowed under) so that no further application of potassium may be necessary. Thus, the so-called "farming out" process may be hastened very materially, and with decided profit on some soils, by applying potassium in some form, especially where the peaty top soil is too deep to admit of reaching the clayey subsoil with the plow.

In its original condition this type of peaty land (that is, a peaty top soil underlain with a clay subsoil), contains abundance of all of the elements of plant food; but the difficulty is that the nitrogen is nearly all in the top soil, while the potassium is very largely in the subsoil (both soil and subsoil commonly contain enough phosphorus), and the chief problem with these particular soils is to bring these elements together in the top soil sufficient for the needs of the growing crop, especially during its earlier growth before its roots reach the lower stratum.

Very satisfactory results have been obtained upon this particular kind of soil, in Ford County, Illinois, simply by means of very deep plowing. Mr. S. K. Marston has a farm in what is called "Vermilion Swamp," in northern Ford County. A careful examination was made of land in this swamp some two years ago. The soil produced very poor crops of corn, but the clayey subsoil was found to be within the reach of the plow, and it was then agreed with Mr. Marston that a trial of deep plowing should be made, and the result has been very successful, as will be seen from the following extracts from a letter recently received from Mr. Marston:

"ONARGA, ILL., October 31, 1903.

"DR. C. G. HOPKINS,

"DEAR SIR:

"I went to my farm yesterday to ascertain the effect of the fertilizers that I had used. My tenant says he can see no perceptible effect. But I can say that deep plowing has done the business. I saw yesterday some of the finest, soundest, heaviest corn I ever saw, and the yield sixty bushels to the acre.

"My tenant is a thorough convert to deep plowing. His plowing this year is nearly a foot deep. We have decided that the soil contains all necessary constituents. Deep plowing seems to be a great success.

"Respectfully,

"S. K. MARSTON."

There is still another kind of peaty swamp land which must be mentioned. This is land whose soil consists of only a few inches of peaty material, which is underlain by sand to a depth of several feet. We have found quite extensive areas of this type of soil, especially in the southeastern part of Kankakee County. The sandy subsoil will usually furnish somewhat more of available potassium than the peaty material will, and the sand, being near the surface, becomes mixed with the peaty material by plowing and cultivation, so that this soil may produce fair crops for a few years. But after the rather small amount of organic matter becomes reduced by cultivation, this type of soil is but little different from ordinary sand soil, which is usually very poor in nitrogen and rather low in all elements of plant food. If the sand contains some clay, which is quite frequently the case, it will be better supplied with potassium than with the other elements. As a rule it is most deficient in nitrogen.

It will be of interest and value to farmers who may have such very sandy swamp soils to know of the results which we have obtained from our "complete fertility tests" on the sand ridge soil in Tazewell County.

GREEN VALLEY SOIL EXPERIMENT FIELD.

This is one of the regular University of Illinois soil experiment fields. It is located in the S. W. 10 of N. W. 40 of N. W. $\frac{1}{4}$ of Sec. 3, Twp. 22 N., R. 5 W. of 3rd P. M., about two miles southwest of Green Valley, Tazewell County, Illinois, on the farm of Mr. J. C. Drake. The soil is typical of the cultivated sand ridge soil, and fairly represents very large areas of sandy land, not only in Tazewell and Mason counties, but also in Whiteside and adjoining counties, Kankakee and adjoining counties, and in smaller areas in many other parts of Illinois.

The Green Valley field contains a series of ten tenth-acre plots in the "complete fertility tests," and also three series of ten plots each in the three-year rotation experiments. As the experiments have been in progress only two years, no definite conclusions can be drawn from the rotation plots, but the "complete fertility tests," which are designed to furnish information as quickly as possible (commercial nitrogen being used instead of waiting for legumes to grow as we do in the rotations),

have already furnished some marked results, as will be seen by reference to Table 6. To those who are familiar with these sand ridge soils, the fact will be appreciated that it is practically impossible to find ten acres of this land with even approximately uniform soil. This experiment field is about as uniform for this land as can well be found; but in each series there are two or three plots which are markedly better land than the remainder of the series. This better soil occupies somewhat lower lying land, which has received some wash from the higher land, and is consequently richer, especially in organic matter and nitrogen, and more productive than the average sand soil. As in all of our soil experiment fields, wherever there is noticeable variation in the soil, the check plot, that is, the plot receiving no treatment, is located on the best land (as in the Momence field, for example), in order that the effects which may be produced by the different kinds of soil treatment shall never be exaggerated, even though they may sometimes be minimized.

For comparative purposes the results obtained on Plots 1 and 2 have practically no value, and they are ignored in computing the averages given in the last three lines in Table 6. It is of interest to note, however, that the yield of corn on those two plots markedly decreased from 1902 to 1903, while every plot receiving nitrogen with either phosphorus or potassium, or both, gave a higher yield in 1903.

TABLE 6.—CROP YIELDS IN SOIL EXPERIMENTS; GREEN VALLEY FIELD, 1902 AND 1903.

Soil plot No.	Soil treatment applied to sand soil.	Yields per acre.			
		Corn, bushels.		Stover, pounds.	
		1902.	1903.	1902.	1903.
401	None	68.7	56.3	3,660	3,860
402	Lime	68.2*	42.0*	2,820*	3,460*
403	Lime, nitrogen	68.6	65.4	2,880	4,180
404	Lime, phosphorus	30.3	24.9	1,940	3,000
405	Lime, potassium	23.1	20.1	1,920	3,080
406	Lime, nitrogen , phosphorus	57.4	69.8	3,080	4,400
407	Lime, nitrogen , potassium	70.0	72.9	3,620	4,940
408	Lime, phosphorus, potassium	49.8	36.6	3,180	3,820
409	Lime, nitrogen , phosphorus, potassium	69.5	69.8	3,580	4,680
410	Nitrogen , phosphorus, potassium	57.2	66.1	3,520	4,540
	L + N, gain for nitrogen	.4*	23.4*	60*	720*
	LP + N, gain for nitrogen	27.1	44.9	1,140	1,400
	LK + N, gain for nitrogen	46.9	52.8	1,700	1,860
	LPK + N, gain for nitrogen	19.7	30.2	400	860
	Average gain for nitrogen	31.2	42.6	1,080	1,373
	Average gain for phosphorus	5.0	7.0	473	233
	Average gain for potassium	11.0	7.4	827	620

*Results based on Plots 1 and 2 are omitted in the averages for reasons explained in the text.

After discarding Plots 1 and 2, we still have a triplicate test as to the effect of each of the elements, nitrogen, phosphorus, and potassium. Thus, in 1902, Plot 4 (lime and phosphorus), produced 30 bushels of corn, while Plot 6 (lime, **nitrogen**, and phosphorus), produced 57 bushels, a gain of 27 bushels for nitrogen. Plot 5 (lime and potassium) produced 23 bushels, while Plot 7 (lime, **nitrogen**, potassium), produced 70 bushels, a gain of 47 bushels for nitrogen. Plot 8 (lime phosphorus, potassium), produced 49 bushels, while Plot 9 (lime, **nitrogen**, phosphorus, potassium) produced 69 bushels, a gain of 20 bushels for nitrogen, the average of these three different tests being 31 bushels gain for nitrogen, as recorded under "average gain for nitrogen." By similar methods it is found that, in 1903, the average increase in yield produced by nitrogen was 42.6 bushels while phosphorus produced an average increase of 5 bushels in 1902 and 7 bushels in 1903, and potassium an increase of 11 bushels in 1902 and 7.4 bushels in 1903.

No one should conclude from these results that the purchase of commercial nitrogen for use on these sand soils is likely to be profitable. The annual application of nitrogen which we have made is 100 pounds per acre (about 800 pounds of dried blood), which is barely sufficient for a crop of 70 bushels (grain and stover). This amount of nitrogen costs \$15.00 in the market. At 30 cents a bushel, it would require 45 bushels of corn to pay for the original cost of the nitrogen. What these experiments teach, and that very emphatically, is the very great importance of growing legumes, or using farm manure, or both, on this sand soil. Although clover does not grow well on this soil, as a rule, we now have conclusive evidence from our rotation experiments, and from numerous trials which different farmers have been induced to make, that cowpeas are well adapted to this soil, and that its productive capacity can be very greatly increased by means of cowpeas alone.

Further investigation is required to determine whether lime, phosphorus, or potassium can be applied to this soil with profit. Certainly they should not be used extensively until the possibilities of cowpeas, soy beans, vetch, or other legumes are better known. There is reason to believe that alfalfa will do well on this soil if it is once well started, as it probably can be by using farm manure and turning under cowpeas, perhaps with the addition of one or two tons per acre of ground limestone. It is strongly recommended that such trials be made with alfalfa (on a small scale at first), providing it with the best possible conditions, including a supply of the alfalfa bacteria, and, if necessary, phosphorus and potassium.

It is believed that this information regarding sand ridge soils can be applied with marked advantage to very sandy swamp soils, especially where the original peaty material was confined to a few inches of top soil which has been worn out or destroyed by cultivation.

SOURCES AND USE OF POTASSIUM.

From the results given in the preceding pages, the fact will be appreciated that the element potassium is a commodity of value, especially for the farmer who has to deal with peaty swamp soils. The commercial value of potassium is about 6 cents a pound for the element in soluble form. There are three common forms of potassium on the market: Potassium chlorid, which contains about 42 percent of potassium; potassium sulfate, containing 40 percent of potassium; and kainit, a crude mineral, containing only 10 percent of potassium. Potassium chlorid is frequently, but very incorrectly, called "muriate of potash." Potassium chlorid contains the two elements, potassium and chlorin, as the name indicates. The word "muriate" has no meaning except that the ending, *ate*, indicates that the compound contains oxygen, which is not the case. "Potash" is a compound of potassium and oxygen, which is not contained in potassium chlorid. It is certainly better for the farmer to say potassium and potassium chlorid and be correct and intelligent about it than to say "potash" and "muriate of potash," and be confused and ignorant as to the nature of the compound.

It should be understood that the law of Illinois requires that every bag of potassium fertilizer sold in the state shall bear a printed label stating the percentage of the element potassium which the material contains, as well as the total number of pounds of material contained in the bag.

If a bag is marked "200 pounds," and the label "42 to 44 percent potassium," this means that the 200 pounds of material contains about 42 percent (or 42 pounds in 100 pounds) of the element potassium, which would make 84 pounds of potassium in the bag, or 840 pounds in a ton, which, at 6 cents a pound, would make the salt worth \$50.40 a ton.

If the bag is marked "200 pounds" and the label "10 to 11 percent potassium," this means that the bag contains about 20 pounds of the element potassium, which would make 200 pounds of potassium in a ton. At 6 cents a pound for potassium, this material would be worth \$12 a ton.

It is true that fertilizer dealers frequently print on the bag the equivalent percentages of "potash," "muriate of potash," "sulfate of potash," etc., the chief effect of which is to make "big figures" and confuse the purchaser, but any farmer can understand the matter of buying potassium if he will look for the percentage of potassium. This is the number of pounds of potassium contained in 100 pounds of the material. A ton would contain 20 times as much potassium, and this is worth 6 cents a pound in Chicago.

It is understood that Armour Fertilizers Works, Union Stock Yards, Chicago, A. Smith & Brother, Tampico, Whiteside County, Illinois, and Chas. H. Chridy, Havana, Mason County, Illinois, are taking out licenses

to sell potassium chlorid, and possibly kainit. Armour Fertilizers Works quote a price of \$50 a ton for potassium chlorid and \$15 a ton for kainit, for ton lots in Chicago, or for carload lots delivered to any point in Illinois. At these prices potassium costs 6 cents a pound in potassium chlorid, and $7\frac{1}{2}$ cents a pound in kainit. A ton of potassium chlorid contains 840 pounds of the element potassium, while a ton of kainit contains only 200 pounds of potassium.

When we remember that a hundred-bushel crop of corn contains 71 pounds of potassium (19 in the grain and 52 in the stover) besides that contained in the roots, it will be seen that 200 pounds of potassium chlorid (84 pounds of the element) will be barely sufficient for the first crop. If, however, only the ear corn is removed from the land, the stalks being pastured and plowed under, only about 20 pounds of potassium are actually removed from the soil each year, even with a very large crop, the larger part of the potassium being thus left for the benefit of succeeding crops. Of course the potassium in the stalks is much less readily available than that in potassium chlorid. Nevertheless, as the stalks decay, the potassium will gradually become available. If the stalks are burned, the potassium remains in the ashes, but usually these are left in windrows, and consequently not well distributed for the next crop.

Farm manure contains about 10 pounds of potassium in a ton, but most farm manure decays slowly, a fact which is evidenced by the lasting effect of manure, its value being commonly greater for the second crop than for the first after its application, while many succeeding crops may show its effect. Horse manure decays much more quickly than cattle manure, and consequently the potassium in horse manure is quite readily available. The potassium in ordinary manure and in corn stalks is probably not worth more than $1\frac{1}{2}$ or 2 cents a pound, as compared with 6 cents a pound for soluble potassium. On this basis, for use on peaty swamp soils, rich in organic matter, nitrogen, and phosphorus, ordinary farm manure is worth about 20 cents a ton when potassium chlorid is worth \$50 a ton. It should not be forgotten that one ton of potassium chlorid contains as much potassium as 84 tons of average fresh farm manure. Manure would be worth only 60 cents a ton for potassium if the potassium were all readily available.

It is certain that if we are raising corn on peaty swamp soil, rich in everything except potassium, and if only about one-fifth of the potassium absolutely required to make a crop is actually removed in the ear corn, it is very unscientific and very poor farm practice to be stingy with the potassium which we supply. On such soils as those on which our experiment fields are located at Tampico, Momence, and Manito, not less than 200 pounds of potassium chlorid per annum should be applied for the first one or two years. After that, if the stalks are not removed from the land, probably 100 pounds a year will be sufficient, and perhaps

this can finally be reduced to 50 pounds a year, as this would furnish 21 pounds of potassium a year, which is slightly more than would be removed in one hundred bushels of corn.

It is well known that in ordinary soils potassium applied in soluble form is not lost by leaching, and it is evident from the experiments reported in this bulletin, especially those on the Manito Field, that peaty soil also has some power to fix and hold potassium from one year to another, even during seasons of abundant rainfall.

METHODS OF APPLYING POTASSIUM SALTS TO THE LAND.

Potassium salts may be applied in the fall or spring, but preferably at least one or two weeks before the corn is planted. The material should never be applied in the hill with corn, for the reason that it may destroy the germinating power of the seed or injure the young plant, and also because the roots of the corn plant do not stay in the hill, but they grow out through the soil in all directions, absorbing moisture and plant food. Corn fertilized in the hill, if the seed or young plants are not injured, frequently makes an abnormally strong growth for a few weeks, and later in the season suffers from dry weather more than ordinary corn, whose roots have developed more normally.

Potassium or other fertilizing material should be applied broadcast or in narrow drills, as a general rule. Any salt of potassium may be applied easily and quickly by hand, sowing or scattering it from the wagon. One farmer in Whiteside County reports having applied 100 pounds to the acre over 22 acres of land in less than three-quarters of a day, a boy being provided to drive the team. Sowing potassium chlorid by hand is less difficult than sowing wheat or oats by hand, because of the necessity of securing a uniform stand of wheat or oats, while it would matter but little if there should be a few square feet now and then which received no potassium. It passes into solution before it becomes fixed in the soil, and will thus be distributed somewhat, and the subsequent preparation of the seed bed and the cultivation of the corn will tend to mix it more uniformly with the soil.

An end gate seeder is a very good implement for applying potassium salts. Probably most farmers could apply the material about as rapidly and more uniformly with an end gate seeder than by hand.

It is good practice to apply the potassium after plowing and then to mix it with the soil by disking, harrowing, etc., in the usual preparation of the seed bed. It should not be applied when the ground is frozen if there is likely to be any overflow or surface drainage before the potassium salt dissolves and soaks into the soil.

REPORTS FROM FARMERS USING POTASSIUM ON PEATY SWAMP SOILS.

Several farmers are using potassium on peaty soils near Manito, both in Mason County and in Tazewell County. Most of them use kainit, because of its low price per ton. (Potassium chlorid is really much cheaper.) About 300 pounds of kainit (30 pounds of potassium) is the usual application. This increases the yield sufficiently so that the farming is not done at a loss, but the yield rarely exceeds half a crop; and when we consider that this peaty swamp soil is one of the richest soils in the state in the element phosphorus, and by far the richest in nitrogen, there is no apparent reason why this soil should not produce 75 to 100 bushels of corn if sufficient potassium is provided. A considerable number of farmers near Tampico have made some use of potassium during the past season, and in all cases I think they have used high grade material; that is, potassium chlorid or potassium sulfate (the sulfate is slightly more expensive than the chlorid.)

As a rule, through careless oversight or thoughtlessness, farmers do not have check plots. Too frequently they do not consider that absolute knowledge has a high money value in farming as well as in other kinds of business. It is a simple matter to leave a two-rod strip of average land across the field, taking care that no potassium is applied to this strip. It is true that the yield of corn will be lower on this strip than where potassium is applied, but it will furnish a direct comparison as to the effect of the potassium, and this knowledge may be worth many times the loss in yield as a guide in subsequent years. This check strip should be left untreated for two or three years at least.

During the season of 1903 the writer visited several fields in Whiteside County where potassium chlorid (or sulfate) had been applied for corn. By comparing the corn on these fields with corn on adjoining farms or fields where no potassium had been used, very marked effects were commonly apparent.

Under date of Nov. 6, 1903, Mr. J. H. Milligan, of Tampico, writes:

"Mr. Wheelock's corn is making from 65 to 70 bushels per acre. This is about 30 to 35 bushels net for potassium.

"Mr. Cortes applied potassium (chlorid or sulfate) at the rates of 40 pounds, 60 pounds, and 100 pounds per acre. The 40 pounds gave no result, the 60 pounds better growth, the 100 pounds makes him corn yielding 50 bushels per acre. He applied in the field on good and bad spots alike. He says where he applied 100 pounds to the acre, the corn grew and yields all about alike, showing no bad spots in growth or yield. He thinks the potassium has made 50 bushels net on all bad spots."

Under date of Nov. 3, 1903, Dr. J. H. Mosher, of Prophetstown, Whiteside County, writes:

"In reply to yours, would say I used muriate of potash of Armour & Co. I paid \$56 a ton. I don't know the percent of potassium. Tenant applied 100 to 125

pounds per acre broadcast. Where applied the yield is increased 30 bushels per acre—from 20 to 50. Tenant says in spots of an acre or so it doesn't show much effect. There may be some other trouble with that land."

"ALKALI" SOILS.

It should be understood that the peaty swamp soils reported in this bulletin are not the same as the so-called "alkali" or "bogus" soils. These "alkali" spots are very numerous in central and northern Illinois. They usually occur in the midst of the very best farming lands. They vary in size from a few square rods to several acres. They are being investigated, and some information regarding them has already been obtained, and it seems appropriate that a brief preliminary report regarding these "alkali" spots should be made in this bulletin, but this report must be considered as tentative and suggestive and not conclusive. Further investigation is needed before complete or definite information regarding these soils can be obtained.

The most common kind of so-called "alkali" spot which we have found does contain alkali, and the soil is not improperly called alkali soil. The alkali, however, is not sodium carbonate, the ordinary strong alkali of the soils of arid countries, but it is magnesium carbonate, a mild alkali. The magnesium carbonate is usually associated with much larger quantities of calcium carbonate (limestone is calcium carbonate). Although magnesium is one of the essential elements of plant food, yet an excessive amount of magnesium carbonate and bicarbonate becomes poisonous to plants, especially to corn and millet.

Usually the magnesium carbonate is more concentrated in the subsoil than in the surface, and if we can provide perfect underdrainage and prevent so far as possible the magnesium carbonate and more soluble bicarbonate from rising to the surface, and also provide abundance of plant food in the surface soil so that the corn roots are not required to live in the subsoil, these alkali soils can be made to grow good corn. In some cases applications of potassium salts may prove beneficial, but as a rule the most practical method for improving these soils is to provide good, deep underdrainage and then plow under coarse organic matter, such as straw, coarse manure, green oats, weeds, etc. This material helps the drainage, tends to prevent the rise of the alkali by retarding surface evaporation, and as it decays it liberates plant food in the surface soil, and it may be that organic acids are also liberated which unite with the magnesium to form less harmful compounds.

We have already ascertained that the magnesium can be removed from the soil by leaching or drainage after being transformed into the perfectly soluble magnesium sulfate by the double decomposition of magnesium carbonate and calcium sulfate, leaving behind harmless calcium carbonate (limestone), and we hope soon to determine whether the quantity and cost of calcium sulfate (gypsum, or land plaster) and the time

required for the leaching process will prove to be too great to permit this to be done economically.

If no manure or other material is at hand, it is well to sow oats on these spots, and if they grow rank and fall down plow them under. One or two heavy crops of green oats plowed under will usually put the soil in condition to grow one or more crops of corn, and with perfect drainage these soils will usually improve with heavy cropping, for they are frequently very rich in all elements of plant food. Plenty of tile, laid deep and made to *work* (if necessary by surrounding them with straw, corn cobs, brush, etc.) is all that some of these spots need to make them grow corn.

METHODS OF SOIL INVESTIGATION.

The Experiment Station does not undertake to analyze miscellaneous samples of soil for private parties. First, because the total annual appropriation for all soil investigations is less than $12\frac{1}{2}$ cents for each quarter section of Illinois land, while it costs at least \$25, or 200 times $12\frac{1}{2}$ cents, to analyze a single sample of soil. Second, because analyses of miscellaneous samples of soil, collected by unauthorized and untrained persons, by inaccurate and non-uniform methods, usually imperfectly representing a single field, or sometimes a mere patch of ground, would be of little value even to the owner of the piece of land, and probably of no value to the agriculture of a state.

That farmers generally understand and appreciate that the State Experiment Station cannot, and ought not, to make such analyses is evidenced by the fact that, with few exceptions, there has been no demand upon us by Illinois citizens for such private work at public expense. That it would be impossible to do such work for all Illinois citizens is also evidenced by the fact that we have received as many as eleven samples of soil from one man with the request that they should all be analyzed.

The investigation of Illinois soils is being conducted, first, by a General Soil Survey, and second, by a Detail Soil Survey. In the general survey the state is divided into very large soil areas, the divisions being based largely upon the soil formation of the areas. The principal type of soil in each great area is then investigated and reported upon. This gives valuable information concerning all of the principal or most extensive types of soil in the State, although it does not give all of the exact boundary lines of these types, and it does not include any investigation of minor or less extensive types of soil, several of which may be interspersed with the principal type of the area. A preliminary report on the general survey has already been made in Circular No. 68, and a more complete report is nearly ready for publication in bulletin form.

The detail survey is being carried on as rapidly as it can be done with accuracy. In the detail survey all the soils in an area which is being surveyed are gone over very carefully by men who are trained for this

work, a complete soil map being made of all the different types of soil in the area. This soil map shows the location, extent, and boundary line of each soil type. In this detail soil mapping the Illinois Experiment Station and the Bureau of Soils of the United States Department of Agriculture are working in close co-operation. Each of these types of soil is then investigated by the Experiment Station, not only by analyzing samples of the soil, but, so far as possible, by pot cultures and by field experiments similar to those described in this bulletin. All soil samples taken for analysis are collected by Experiment Station men, who are familiar with the most accurate and scientific methods of sampling soils, in order that the samples shall be taken by uniform methods which shall render them comparable, and that they shall be truly typical samples of the different strata of the kind of soil which they are to represent. If the samples do not truly represent the soil type, the analyses would, of course, be practically worthless. It will never be possible for the Experiment Station to analyze the soil from every field of every Illinois farm, but it is possible and practicable to map the soils of the state in detail, and then to analyze representative samples of every type, so that ultimately every farmer can know what type or types of soil cover his farm, what the average composition is of each type, what crops are best adapted to the different soils, and what kinds of soil treatment or management are required to maintain or increase the crop yields.

More than one-tenth of the state has now been covered by the detail soil survey, and the samples which have been collected are now being analyzed and the results will be published in bulletin form from time to time, as the work progresses. Every farmer should make the greatest possible use of the reports on the general survey until such time as the detail survey is extended over his land. Circular No. 68, already published, furnishes information which more than half the farmers in Illinois can apply to their own soils, if they will study it as other business men study their business.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

BULLETIN NO. 94.

NITROGEN BACTERIA AND LEGUMES

(WITH SPECIAL REFERENCE TO RED CLOVER, COWPEAS, SOY BEANS,
ALFALFA, AND SWEET CLOVER, ON ILLINOIS SOILS).

By CYRIL G. HOPKINS.

Work and Knowledge are a stronger team than Work and Work.



URBANA, ILLINOIS, FEBRUARY, 1904.

SUMMARY OF BULLETIN No. 94.

1. Soil nitrogen cannot be used by plants until it is changed to the form of nitrate nitrogen by the nitrifying bacteria. Page 307

2. Atmospheric nitrogen cannot be used by any agricultural plants, excepting legumes, and even leguminous plants have no power to obtain nitrogen from the air unless they are provided with the proper nitrogen-gathering bacteria. Page 309

3. As a rule each important agricultural legume must have its own particular species of bacteria. Page 311

4. The frequent failure of red clover in normal seasons, especially on normal soils occupying the highest land, is undoubtedly due in part at least to the absence of the proper bacteria (sometimes the soil lacks lime or phosphorus). Page 313

5. On the very acid soils, where clover has never been grown successfully, applications of ground limestone should be made where legumes are to be grown. Page 315

6. Cowpeas need not be inoculated, because the cowpea bacteria are usually either present in the soil or are introduced with the seed in sufficient numbers to effect a good degree of infection if the soil is suitable and if cowpeas are seeded upon the same land for two successive years. Page 317

7. Cowpeas grown on infected soil on the University of Illinois soil experiment field contained four times as much nitrogen as the same kind of cowpeas grown on similar land which was not infected. Page 319

8. As a rule soy bean fields should be inoculated when first seeded to soy beans, otherwise they may be grown on the same land for three or four years before the soil becomes thoroughly infected. Page 320

9. Investigations, reported in this bulletin, furnish conclusive proof that infected sweet clover soil can be used for inoculating alfalfa fields and with the same results as are obtained when the infected soil is obtained from an old alfalfa field. (Sweet clover is a tall, rank-growing, sweet-scented leguminous plant widely distributed over Illinois, especially along the roadsides in the northern and central parts of the state, and in many places in bottom lands in southern Illinois.) Page 324

10. This bulletin will be sent free of charge to any one interested in Illinois agriculture upon request to E. Davenport, Director Agricultural Experiment Station, Urbana, Illinois; and, if so requested, the name of the applicant will be placed upon the permanent mailing list of the Experiment Station, so that all bulletins will be sent to him as they are issued.

Conclusions

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NITROGEN BACTERIA AND LEGUMES

(WITH SPECIAL REFERENCE TO RED CLOVER, COWPEAS, SOY BEANS,
ALFALFA, AND SWEET CLOVER, ON ILLINOIS SOILS).

By CYRIL G. HOPKINS, CHIEF IN AGRONOMY AND CHEMISTRY.

Among the several different classes or groups of bacteria there are two which are of special importance to agriculture because of their relation to the element nitrogen, this being commonly considered the most valuable element of plant food.* These two classes of bacteria are, first, the nitrifying bacteria, and, second, the nitrogen-gathering bacteria.

THE NITRIFYING BACTERIA.

The nitrifying bacteria are those which have the power to form nitrates. In the following brief discussion of this subject we include at least three species of bacteria which by their combined or successive action have the power to transform organic nitrogen into nitrate nitrogen, which is a suitable form of nitrogen for plant food. For the exact information which we now have regarding the nitrifying bacteria we are indebted to the researches of Pasteur and Schlösing and Müntz of France, Winogradsky of Russia, Warington of England, and others.

The nitrogen in the soil is almost entirely in organic compounds; that is, the nitrogen (which is a gas in the free, or uncombined, state) is united or combined with other elements, notably with carbon, hydrogen, and oxygen, in the form of partially decayed vegetable or organic matter. (By organic matter we mean matter which has been formed by the growth of some organism, either plant or animal, as grass or flesh.) Plants cannot use the free nitrogen of the air as plant food, neither can they use the organic compounds of nitrogen which occur in the soil. There

*It should be remembered that there are ten essential elements of plant food each of which is of equal importance to the plant, for if the plant is deprived of any one of the ten essential elements it is impossible for it to develop and mature. Carbon has no market value as plant food because the plant obtains carbon in the form of carbon dioxide, a gas which is present everywhere in the atmosphere and which the plant inhales through its leaves. Both hydrogen and oxygen are without market value because they are the elements which compose water, a liquid compound which plants absorb through their roots. Calcium, magnesium, iron, and sulfur have no market value as elements of plant food because they are present in practically all soils in abundance as compared with the amounts required in plant growth. The three elements nitrogen, phosphorus, and potassium, do have market values, because they are required by plants in very considerable quantities, and they are present in most soils in rather limited amounts, and when the available supply of any one of these elements becomes too much reduced in a soil the crop yield also becomes reduced. For further information regarding the use of these elements of plant food on Illinois soils, see Circular No. 68, "Methods of Maintaining the Productive Capacity of Illinois Soils."

are at least three different kinds of bacteria, and also three different steps or stages involved in the process of nitrification, the nitrogen being changed from the organic compounds first into the ammonia* form, second, into the nitrite form, and third into the nitrate form. During the process the nitrogen is separated from the carbon and other elements composing the insoluble organic matter, and is united or combined with oxygen and some alkaline element (as calcium) to form the soluble nitrate, such as calcium nitrate, which is one of the most suitable compounds of nitrogen for plant food. Calcium is the alkaline element contained in lime or limestone. The name *calcium nitrate* indicates just what elements this compound contains; namely, calcium, nitrogen, and oxygen. (In the names of compounds the ending *-ate* always means oxygen.)

This is the general process of nitrification in which the nitrifying bacteria transform or transfer the nitrogen from insoluble organic compounds into soluble compounds in which it may serve as available plant food. The nitrate which is thus formed may be calcium nitrate or magnesium nitrate or potassium nitrate or even sodium nitrate, depending upon which of these alkaline elements is present in the most suitable form. If no alkaline element is present in available form then no nitrates can be made in the soil. One of the reasons for applying ground limestone to soils which are deficient in lime is to furnish the element calcium in suitable form for the formation of nitrates in the process of nitrification. Ground limestone is calcium carbonate (CaCO_3), a compound containing one atom of calcium (Ca), one atom of carbon (C) and three atoms of oxygen (O_3). This is the same form of lime which is contained naturally in limestone soils—soils which are noted for their great productiveness—and it is generally the most economical form of lime to use for correcting soil acidity and promoting nitrification.

In the process of nitrification, that is in the formation of nitrates, there is required, not only the presence of calcium, or some other alkaline element, in suitable form, but also a good supply of the element oxygen; for calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, contains one atom of calcium (Ca), two atoms of nitrogen (N_2), and six atoms of oxygen (O_3)₂, in each molecule as indicated in the formula, $\text{Ca}(\text{NO}_3)_2$. Magnesium nitrate, $\text{Mg}(\text{NO}_3)_2$, potassium nitrate, KNO_3 (K is from the Latin word *Kalium*, which means potassium), and all other nitrates, also, contain oxygen. The supply of oxygen for the formation of nitrates in the soil comes from the air, which consists of about twenty percent oxygen, seventy-eight percent nitrogen, and two percent of other elements and compounds, as argon, carbon dioxid, CO_2 , water vapor, H_2O , etc. One of the important effects of cultivation, or tillage, is that it permits the air more freely to enter the soil, and thus promotes nitrification.

* Technically this first step is preliminary to, and not a part of, nitrification.

THE NITROGEN-GATHERING BACTERIA.

As stated above, the nitrogen naturally in the soil is contained almost entirely in the organic matter. Any process which tends to decompose or destroy this organic matter, such as nitrification or other forms of oxidation, will also tend to reduce the total stock of nitrogen in the soil. Because of this fact the matter of restoring nitrogen to the soil becomes of very great importance. Of course a part of the nitrogen removed in crops may be returned in the manure produced on the farm; and nitrogen may also be bought in the markets in such forms as sodium nitrate (containing 15 to 16 percent of nitrogen), ammonium sulfate (containing 20 to 21 percent of nitrogen), and dried blood (containing 12 to 15 percent nitrogen); but, when we bear in mind that such commercial nitrogen costs about 15 cents a pound, and that one bushel of corn contains about one pound of nitrogen, it will be seen at once that the purchase of nitrogen cannot be considered practicable in general farming, although in market gardening, and in some other kinds of intensive agriculture, commercial nitrogen can often be used with very marked profit.

Nitrogen is removed from the soil not only in the crops grown, but also, and frequently in larger amounts per annum, in the drainage waters, and in some other ways, as by denitrification and by the blowing and washing of the surface soil. Professor Snyder, of the Minnesota Experiment Station, has shown that during a series of years the total loss of nitrogen from some Minnesota soils in some cases amounts to several times the amount actually used in the crops produced.

Considering all of these facts, and the additional facts that there are about seventy-five million pounds of atmospheric nitrogen resting upon every acre of land, and that it is possible to obtain unlimited quantities of nitrogen from the air for use of farm crops, and at very small cost, the inevitable conclusion is that the inexhaustible supply of nitrogen in the air is the store from which we must draw to maintain a sufficient amount of this element in the soil for the most profitable crop yields.

It is often stated that leguminous plants, such as clover, have power to obtain free nitrogen from the air. This is not strictly true. Red clover, for example, has no power in itself to get nitrogen from the air. It is true, however, that the microscopic organisms* which commonly live in tubercles upon the roots of the clover plant do have the power to take free nitrogen from the air and cause it to unite with other elements to form compounds suitable for plant food. The clover plant then draws

*Among the scientists who were prominent in making these discoveries regarding the action of bacteria in the fixation of atmospheric nitrogen were Hellriegel, Willfarth, and Nobbe in Germany, Atwater in America, Lawes and Gilbert in England, and Boussingault and Ville in France.

upon this combined nitrogen in the root tubercles, and makes use of it in its own growth, both in the tops and in the roots of the plant.

These nitrogen-gathering bacteria live in tubercles upon the roots of various leguminous plants,* such as red clover, white clover, alfalfa, sweet clover, cowpeas, soy beans, vetch, field-peas, garden-peas, field and garden beans, etc. These tubercles vary in size from a pinhead to a pea, varying with the different kinds of plants, being especially small upon some of the clovers, and very large upon cowpeas and soy beans.

*It may be well to call attention to the fact that there are numerous instances where two different kinds of plants live together in intimate partnership relation. If only one of the two plants receives benefit from this relationship or association, then the plant receiving the benefit is called a parasite. Thus the mistletoe is a parasite upon the elm or gum or other tree on which it lives. The mistletoe draws its nourishment from the tree. The tree is injured rather than benefited by the mistletoe. Dodder is also a parasitic plant, living upon other plants, except during the early part of its growth. Ticks and lice are common examples of animal parasites living upon other animals.

In some cases a relationship exists which is not parasitic but symbiotic. The term symbiosis, which is commonly used by biologists to define this relationship, means living together in mutual helpfulness. The association of bees and flowers may serve to illustrate this mutual helpfulness, although this is not an example of intimate symbiosis. Thus the bees obtain their food from the flowers and, in turn, the flowers, many of them, are incapable of producing seed or fruit unless the pollen is carried from the male flower to the female flower by bees or other agencies. It is well known that plant lice and ants are mutually helpful.

Likewise the association of nitrogen-gathering bacteria and leguminous plants is a relationship of mutual helpfulness and this is one of the best illustrations of what is meant by symbiosis. The legume furnishes a home for the bacteria and also furnishes in its juice or sap most of the nourishment upon which the bacteria live. The bacteria, on the other hand, take nitrogen from the air contained in the pores of the soil, and cause this nitrogen to combine with other elements in suitable form for plant food which is then given up to the legume for its own nourishment.

Another illustration of remarkable parasitism, if not, indeed, one of true symbiosis, is found in the common lichens living upon rocks and trees. The lichen is not a single plant, but two plants—an alga, which lives upon the wood or stone, and a fungus which lives upon the alga. Algæ also live in the free state separate from fungi, and the present opinion of botanists seems to be that when the two are associated in the form of lichens this association is not detrimental, but rather beneficial, to the alga, as well as to the parasitic fungus. If this is true, then it is another case of true symbiosis. (There is reason to believe that the fungus has some power to feed upon atmospheric nitrogen, and then to furnish combined nitrogen to the alga upon which it lives.)

In the symbiosis of leguminous plants and nitrogen-gathering bacteria we have a partnership or relationship of immeasurable value to agriculture. Here is a class of plants (legumes) that are capable of consuming or utilizing nitrogen in quantities larger than could possibly be obtained from ordinary soils for any considerable length of time. They have no power in themselves of taking nitrogen from the atmosphere, and to them the symbiotic relation with this low order of plants (the nitrogen-gathering bacteria) is especially helpful, and for the best results it is absolutely necessary.

The tubercles are, of course, easily seen with the eye, but the tubercle is only the home of the bacteria, somewhat as the ball upon the willow twig is the home of the insects within. The bacteria themselves are far too small to be seen with the unaided eye, although they can be seen by means of the most powerful microscope. Several million bacteria may inhabit a single tubercle. It is not necessary to see the bacteria, because if we find the tubercles upon the roots of the plant, we know that the bacteria are present within, as otherwise the tubercle would not be formed.

Although the plant itself, as clover, for example, has no power to feed upon the free or uncombined nitrogen in the air, yet these nitrogen-gathering bacteria do have the power to absorb the free nitrogen and cause it to combine with other elements, forming nitrates or other compounds which are suitable forms of nitrogen for plant food.

It has also been demonstrated that, as a rule, there are different species of nitrogen-gathering bacteria for markedly different species of leguminous plants. Thus we have one kind of bacteria for red clover, another kind for cowpeas, another kind for soy beans, and still a different kind for alfalfa.*

THE RED CLOVER BACTERIA.

That clover has no power in itself to gather atmospheric nitrogen, and that the bacteria do have power to feed the clover plant with nitrogen gathered from the air is very easy to demonstrate. It is one of the regular laboratory practices of the students in soil fertility in the Agricultural College to make this demonstration. Plate 1 is an illustration of such student work. The two pots which are shown were provided with all elements of plant food, excepting the one element nitrogen. Thus far the two pots are exactly alike. Each contains no nitrogen, as indicated by the label "No N." Each pot is planted with the same number of red clover seeds. To the right-hand pot, however, some bacteria ("Bac.") were added, while none were added to the left-hand pot. These bacteria were obtained by taking about one pound of soil from a clover-field where abundance of tubercles were found on the

*There are some noteworthy exceptions to this rule (see following pages for illustration), and there is some evidence that, by a comparatively long process of breeding, or evolution, the bacteria which naturally live upon one kind of legume may gradually develop the power to live upon a distinctly different legume to which they were not at first adapted. Of course this process of forcing bacteria to live upon a legume to which they are not naturally adapted has little or no practical value because it is unnecessary if there is a species of bacteria which naturally lives upon the same legume. On the other hand, if, by any such process of breeding, or evolution, a species of nitrogen-gathering bacteria could be developed which could live on a non-leguminous plant, as corn, for example, it would be of incalculable practical value. As yet the efforts of bacteriologists, working on this problem, have given only negative results, so far as known to the writer.

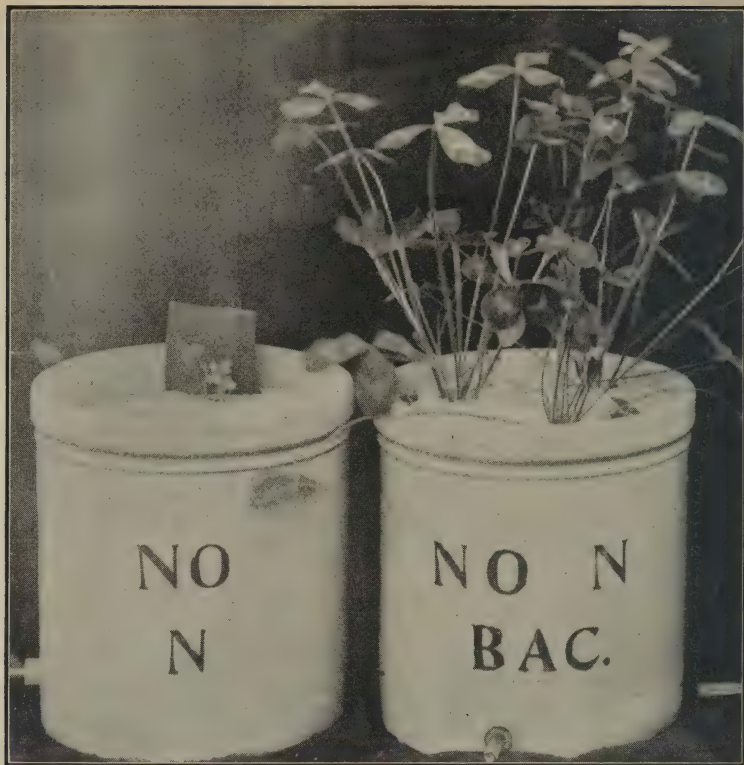


PLATE 1. RED CLOVER: EFFECT OF BACTERIA. NO NITROGEN IN THE SOIL OF EITHER POT.

clover roots, adding this soil to about one quart of pure water, shaking for a few minutes, allowing the soil to settle, then taking a small quantity of almost clear solution, and adding it to the pot which we wished to inoculate with the red clover bacteria. Aside from the addition of these microscopic bacteria to the right-hand pot, these two pots were treated exactly alike throughout the experiment. It will be plainly seen that where the bacteria were added the clover was furnished with sufficient nitrogen to make a strong and luxuriant growth, while without the bacteria the clover (in the left-hand pot) only germinated and made what little growth it could with the small amount of nitrogen contained in the seed. This result is the difference between success and failure of the clover crop.

In general the clover bacteria are well distributed over the northern and central part of Illinois, but we now have some very strong evidence that they are not well distributed in some soils of large area in southern Illinois. There is also some evidence that they were not originally

present even in the soils where they are now found in great abundance; and, furthermore, it seems very probable that these bacteria may cease to live in a soil where they have once been present, provided clover is not grown on the land for several years.

It will help us to understand this matter if we bear in mind that the home of these bacteria is the tubercle upon the clover root. It is quite evident that they will continue to live upon the decaying tubercles or roots for three or four years after the clover plant has been killed. On the other hand, we have some notable evidence that the bacteria do not continue to live in a soil after five or six years' continuous cropping with absolutely no clover growing on the land during those years. It is a simple matter for any one to determine whether the bacteria are present or not, for the tubercles which are formed if the bacteria are present are plainly seen attached to small roots. They look somewhat like miniature potatoes, varying in size from pinheads on clover to peas on soy beans or cowpeas. (See Plates 2 and 4.) It is important to remember that the bacteria live in the soil and not in the seed. •

When clover is cut for seed, it is frequently left to lie upon the ground until the straw becomes half rotten and very dirty; and, consequently when it is threshed, it practically always happens that there is at least some small amount of dust and dirt taken with the seed. This dirt is almost sure to carry with it some bacteria from the soil. If these few bacteria are scattered with the clover seed when it is sowed they will inoculate at least a few plants, and if they are allowed to multiply on these plants, and especially if the same field is repeatedly seeded with clover, the soil will ultimately become thoroughly infected with the clover bacteria. Of course they may be carried from one part of the farm to another, or even from one farm to another, by various agencies, as dust or wind storms, surface drainage or flood waters, manure made from clover hay, implements used in cultivating the soil, etc., etc.

Many of the older farmers of Illinois have stated to the writer that when this country was very new it was commonly found difficult to get a "catch" of clover on new land. After a good "catch" was once gotten, then it was easier to get clover to grow on that land the next time. There was a saying among the farmers that clover would not do well until they got the "wild nature" out of the land. Their final success was undoubtedly due, not to getting anything out of the land, but rather to getting the bacteria into the land. Several Illinois farmers have reported some quite remarkable results from very light applications of the clover chaff or straw (obtained in hulling clover) in its beneficial effect on clover on land where it was otherwise difficult to get a "catch." There is a somewhat general belief among farmers of long experience that clover straw or chaff has some special value in getting a catch of clover aside from its value as manure or for the seed which it sometimes contains.

Manager F. A. Warner of the Sibley Estate, Ford County, recently stated to the writer that they had had very great difficulty to get clover to grow when they first began growing clover on that large estate, some six or eight years ago, although, after a good crop was once secured, they rarely had any further difficulty in getting a catch of clover on the same land.

On the common gray prairie soil of the Lower Illinoisan Glaciation, in southern Illinois, the commonest type of soil in more than twenty counties, practically no red clover is grown. In the spring of 1903 we seeded red clover on that type of soil in three places; namely, on the University of Illinois soil experiment fields near Edgewood, Effingham County, near Du Bois, Washington County, and near Cutler, Perry County. On certain plots the soil acidity had been corrected with lime and an abundant supply of phosphorus (in bone meal) had been provided, potassium also having been added on some plots. These fields were carefully examined the latter part of June, and at Cutler and Du Bois the clover was found to be dead or dying, and no tubercles could be found upon the clover roots, although on the clover which had been seeded at about the same time on the University fields at Urbana the root tubercles were found in great abundance. At Edgewood a few tubercles were found and the clover appeared to be growing fairly well. Infected red clover soil was at once procured and scattered over the fields at Edgewood, Du Bois, and Cutler, but it was evidently too late to be of any marked benefit. At Cutler and at Du Bois the clover was a complete failure. (It will be tried again next year.) At Edgewood it continued to grow fairly well, and its progress next season (1904) will be watched with much interest. It should be stated that the Experiment Station has been growing clover for several years with varying degrees of failure on land adjoining the present clover field at Edgewood, and it is possible that this year's apparent success from the start is due in part at least to the bacteria which have been incidentally introduced and multiplied year after year and scattered over the adjoining land by wind and dust storms. Before the close of the season the tubercles developed in abundance on the roots of the clover at Edgewood.

An experience reported by Professor Herbert W. Mumford, of the Animal Husbandry Department of this university, will be of interest and value in this connection. Professor Mumford commonly grows clover in his rotations on his own private farm, but he states that at one time one particular field was cropped continuously with timothy, oats, and corn for some six years or more without any clover whatever. It was then again seeded to clover, but the crop made a complete failure, although on other land where clover had been grown more recently a successful clover crop was grown from the same kind of seed seeded at about

the same time. The following year this particular field was again seeded to clover. This time the "catch" was not a total failure, but it was too poor to save, and it was plowed up and the land again seeded to clover the next year, and an excellent catch of clover resulted. After this, clover was frequently grown on this field, and no special difficulty was had in getting good crops.

While the failure of clover may often be due to drouth, and in some places due to soil acidity (lack of lime), and sometimes even due to an insufficient supply of available phosphorus or of potassium, we now know with certainty that it sometimes fails because of the absence of the nitrogen-gathering bacteria, especially on land which has never grown clover, and probably also on land which has not grown it recently. We should always remember that the bacteria do not thrive in strongly acid soils. Even though they may sometimes live in such soils and perhaps produce some tubercles upon the roots of certain hardy, strong growing legumes, like cowpeas, nevertheless we are obtaining some strong evidence that in such acid soils they have but little power to gather nitrogen from the air. That ground limestone is the most economical and satisfactory material to use in correcting the acidity of soils is strongly indicated by the information we have thus far obtained. On the upland prairie soils of the Lower Illinoisan Glaciation where red clover has never been grown successfully, largely because of the acidity of the soil, it will undoubtedly be helpful and profitable not only to correct the acidity of the soil with ground limestone, but also to secure infected soil from some field of timber land or bottom land where red clover is growing, well provided with root tubercles, and inoculate the field with it. This soil should be collected to a depth of three or four inches and scattered over the prairie land at the rate of a few hundred pounds per acre at the time the clover is seeded or before.

THE COWPEA BACTERIA.

Plate 2 is made from a photograph of a cowpea root with the tubercles upon it. This illustration shows the cowpea tubercles at nearly natural size, which is about as large as the seed of ordinary garden peas.

The cowpea bacteria are already quite widely distributed in southern Illinois, especially where this crop has been grown for several years, but they are not common in the soils of other parts of the state. It is doubtful, however, if it is necessary or even worth while to take the trouble to inoculate soil for cowpeas. Some few tubercles almost invariably develop on cowpea roots the first year they are seeded, even where they have never been grown before, and if seeded the second year on the same land the plants are usually abundantly provided with root tubercles.

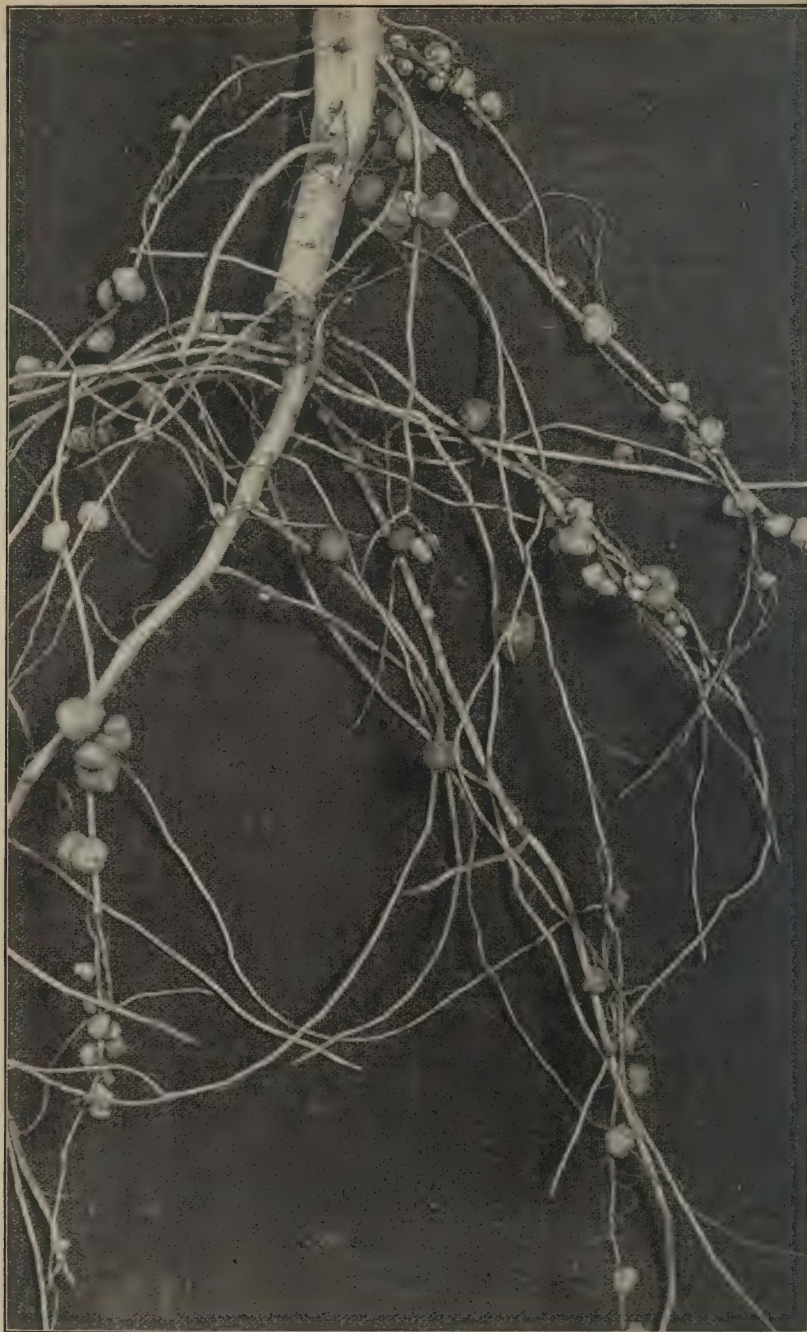


PLATE 2. COWPEA ROOT TUBERCLES, NATURAL SIZE.

Just why the cowpea bacteria develop so rapidly even without special inoculation is not definitely known. It may be that the same bacteria also live on some other leguminous plant which is more or less widely distributed over the state, but it seems more likely that the bacteria are brought with the seed. As a matter of fact, the cowpea harvest is usually dirty. This is an annual plant, and consequently the crop is grown on recently plowed land and is sometimes cultivated during the season. Cowpeas are commonly harvested with a mowing machine and then raked up on the loose ground. When they are threshed more or less dirt remains with the seed. Furthermore, the seed coats are not infrequently cracked, thus providing an excellent place for the lodgment of particles of soil.

Whether it would be profitable to inoculate the land for cowpeas would depend very largely upon the difficulty or cost of obtaining the infected material. If soil thoroughly infected with the cowpea bacteria can be scattered over the land at the rate of about 2,000 pounds to the acre at a cost of \$1.00 or less per ton, it might prove profitable. It is doubtful if a light application of 100 or 200 pounds would produce any very marked effect in the yield the first season. After the soil becomes well infected the cowpeas then obtain much nitrogen from the air, and the yield of cowpeas is likely to be largely increased. Of course there is no fixation of atmospheric nitrogen if there are no tubercles on the roots.

In 1902 several plots of cowpeas were seeded on the soil experiment field at the university. One of these plots (404) had become thoroughly infected with the cowpea bacteria because of its being so situated that more or less surface drainage water flowed over it from an adjacent field upon which cowpeas had been grown for three successive years. Another plot (408), owing to a slightly different situation, had not become infected. The two plots were seeded in July after a crop of oats had been removed from the land. Within three weeks after seeding, numerous root tubercles could be found on the plants on the infected plot. Later on, ten average consecutive plants were taken up as completely as possible, and 412 tubercles were found on the roots, making an average of more than 40 tubercles to the plant. On Plot 408 only an occasional plant was found infected, and such plants would usually have only a single large tubercle on their roots. Ten average plants not infected were collected from Plot 408 for comparison with the ten infected plants from Plot 404.



PLATE 3. COWPEAS: EFFECT OF BACTERIA IN ORDINARY ILLINOIS BLACK PRAIRIE SOIL.

Plate 3 shows these two bunches of plants, the infected plants with root tubercles on the *right*, and the plants without tubercles on the *left*. Four more sets of ten plants each were then collected, two sets from Plot 404 and two from Plot 408. Each set of infected plants was separated into three parts, (1) tops, (2) roots, (3) tubercles; and each set of plants not infected was separated into (1) tops, and (2) roots. All of these samples were dried and analyzed for nitrogen. The results obtained are shown in Table I.

The results clearly show the very great value of the nitrogen-gathering bacteria in growing cowpeas. In each of the separate trials A, B, and C, the infected plants contained about twice as much total dry matter as the plants not infected. The infected plants also contained a much higher percent of nitrogen than the plants not infected, the infected plants containing 4.09 to 4.33 percent in the tops and 1.45 to 1.53 percent in the roots, while those not infected contained only 2.32

TABLE I.—FIXATION OF NITROGEN BY COWPEAS.

COWPEA PLANTS.		Dry matter, cgs.	Nitrogen, content, percent.	Nitrogen, amount, cgs.	Nitrogen fixed by bacteria, cgs.
No.	Part.				
A1—Ten plants, with bacteria present.....	Tops	3580	4.09	146	125
	Roots	620	1.45	9	
	Tubercles	190	5.97	11	
	Total	4390		166	
A2—Ten plants, without bacteria	Tops	1560	2.42	38	
	Roots	300	.88	3	
	Total	1860		41	
B1—Ten plants, with bacteria present.....	Tops	3970	4.31	171	140
	Roots	690	1.47	10	
	Tubercles	300	6.05	18	
	Total	4960		199	
B2—Ten plants, without bacteria	Tops	2060	2.69	55	
	Roots	430	.88	4	
	Total	2490		59	
C1—Ten plants, with bacteria present.....	Tops	3300	4.33	143	124
	Roots	520	1.53	8	
	Tubercles	290	5.76	17	
	Total	4110		168	
C2—Ten plants, without bacteria	Tops	1730	2.32	40	
	Roots	400	.88	4	
	Total	2130		44	

to 2.69 percent in the tops and .88 percent in the roots. Besides this, the tubercles on the infected plants contain 5.76 to 6.05 percent of nitrogen. In these young and rapidly growing plants the tubercles are much richer in nitrogen than any other part of the plant. It should be stated that as the plants approach maturity the nitrogen is largely absorbed from the tubercles and stored in the tops and roots. At the time these plants were taken up the tubercles actually contained more nitrogen than the roots. The infected plants contained nearly four times as much nitrogen as the plants not infected, and about three-fourths of the total nitrogen in the infected plants was obtained from the air. The roots and tubercles of the infected plants contained six to seven times as much nitrogen as the roots of the plants not infected.

THE SOY BEAN BACTERIA.

Soy bean bacteria are evidently much less likely to be carried with the seed than are the cowpea bacteria. The soy bean plant grows more erectly than the cowpea (see Circular No. 69, "The Cowpea and Soy Bean in Illinois"), and the crop is quite commonly harvested with a self-

binder which keeps it quite free from dirt. The soy bean seed is nearly round and smooth, and the seed coat is not commonly cracked. These facts may explain why the soy bean seed carry so few bacteria as compared with cowpeas.

On one of the soil experiment fields on the university farm at Urbana, where soy beans have been grown for three years, no tubercles could be found on the plants either the first or second year, and only an occasional plant with tubercles could be found the third year. In 1902 a series of plots, some of which had been treated in different ways with applications of limestone, phosphorus, and potassium, were seeded with soy beans. No tubercles could be found at any time during the season on the soy beans growing on any of the different plots. In 1903 the same plots were again seeded to soy beans, and at the same time part of each plot was inoculated with infected soy bean soil drilled in with the seed at the rate of about 500 pounds of infected soil to the acre. When the plants were only a few weeks old tubercles were to be found upon many plants growing where the infected soil had been applied, and before the close of the season at least half of these plants in the inoculated part of the field had one or more tubercles upon their roots, and some plants could be found whose roots were abundantly provided with tubercles. (See Plate 4.)

On the uninoculated part of the field soy bean plants were examined probably fifty times during the season, several plants being taken up each time, but not a single tubercle was found at any time, notwithstanding that this was the second crop of soy beans upon this soil. Of course the inoculated part of the field did not become sufficiently infected to markedly benefit the 1903 crop, but it is planned to grow soy beans upon this field again in 1904 when the bacteria will doubtless have multiplied sufficiently to produce marked results in the growth of the crop.

From these and from other somewhat similar experiments it is concluded that as a rule soy beans should be inoculated when they are first seeded, and that they should then be grown a second year upon the same land. If soy beans are afterward grown upon this land once in every three or four years, the soil will doubtless remain well infected with the soy bean bacteria.

It is believed that 100 pounds of infected soy bean soil per acre will be sufficient to produce a thorough infection the second year, and it is improbable that one ton of infected soil per acre would produce a thorough inoculation the first season. One ton is only twenty times 100 pounds, while one tubercle which will be produced during a single season from a single bacterium may contain many million bacteria, thus it will be seen that it will be more economical to inoculate rather lightly and allow the bacteria to multiply themselves rather than to inoculate heavily at great expense.



PLATE 4. SOY BEAN ROOT TUBERCLES, NATURAL SIZE.

It may be stated that the infected soy bean soil used in these experiments was obtained from Mr. A. A. Hinkley of Du Bois, Illinois, who has been growing soy beans on the same land for many years until it has become well infected. Mr. Hinkley has consented to furnish infected soy bean soil so far as he is able to do without serious interference with his regular work, to any one who may desire it, at a price which will cover his expense and loss. This will probably amount to about \$1.00 for the first 100 pounds and fifty cents for each additional 100 pounds, in the shipment, including the cost of bags, the purchaser to pay freight from Bois station, which is located in Washington County, Illinois, on the Illinois Central Railroad.

THE ALFALFA AND SWEET CLOVER BACTERIA.

That soil inoculation with alfalfa bacteria is commonly of very great value in growing alfalfa has been shown very conclusively by the investigations reported in Bulletin No. 76,* "Alfalfa on Illinois Soil." In some places, however, inoculation was found to be unnecessary. A careful and extensive investigation of alfalfa growing in different parts of Illinois revealed the fact, as stated in Bulletin 76, "that the alfalfa bacteria are certainly present in some places in the state while in most other places they are certainly not present in sufficient number to become of appreciable assistance to the alfalfa within three or four years, and the question naturally arises how it happens that some fields are already infected while others are not." It was suggested in that bulletin that the alfalfa bacteria may "live on some other plants besides alfalfa and that one of these plants is native or has been introduced in certain sections" of the state. It was also suggested "that a few bacteria are always carried with alfalfa seed, and that if the alfalfa is grown continuously or repeatedly in any place the soil will finally become thoroughly infected, and the bacteria will then be carried by flood waters, dust storms, etc., over adjoining fields, and possibly for long distances, especially along river valleys." This latter suggestion was known to be a fact at the time it was written; and subsequent investigations have furnished conclusive proof that the alfalfa bacteria do live upon another plant; namely, the ordinary sweet clover (*melilotus alba*). This is a rank-growing leguminous plant, frequently reaching a height of four to six feet. When young it markedly resembles alfalfa, but it can easily be distinguished by its characteristic odor when cut or bruised, as by rubbing between the hands.

*In this connection attention is called to the fact that the so-called "spot disease" of alfalfa, which is not uncommon in the western states, especially during wet seasons, became somewhat prevalent in Illinois in 1903. When the effect of this disease becomes marked, the leaves turn yellow and growth is retarded. If this occurs the alfalfa should be clipped. This is the only effective remedy known to be practicable. Seeding alfalfa with a light nurse crop is gaining favor in Illinois.

As the sweet clover approaches maturity it differs very much from alfalfa. The sweet clover grows very tall, and usually branches from a main stem. It has white flowers (there is also a less common yellow variety), and the seeds are borne in small round pods (usually containing only one or two seeds each), arranged on long slender spikes, each spike bearing many pods. The alfalfa commonly grows about two and a half feet high, with many stems growing from the crown of the root, especially after it is two or three years old. It bears purple flowers and peculiar spiral-shaped seed pods. Sweet clover is a biennial plant, dying after reaching maturity, which commonly occurs the second year of its growth. Like many other biennial plants, it probably often lives more than two years if not allowed to produce seed. Alfalfa is a perennial plant, and it is said that there are alfalfa fields which have been cut annually for more than fifty years without reseeding. The similarity of alfalfa and sweet clover when young, and also the similarity of the tubercles formed on the roots of each have long been noticed, and the possibility of the same bacteria living upon both plants has already been suggested in the agricultural press.

During the season of 1903 the writer spent some time in the northern part of Illinois in connection with the general and detail surveys of Illinois soil. Many new fields of alfalfa were observed, and they were carefully examined for root tubercles. In Winnebago County, where sweet clover is very prevalent along roadsides and in waste places, it was noted that the abundance of root tubercles on the alfalfa plants seemed to be closely related to the presence of sweet clover in the vicinity, strongly indicating that the bacteria which live upon sweet clover were also at home upon the alfalfa roots. These indications were strengthened by further investigations in Lake County, especially upon the Fowler farm, near Lake Villa, where a field of alfalfa seeded last spring without artificial inoculation was found to be thoroughly infected with the bacteria, and growing vigorously with a good dark green color. This field had a few sweet clover plants growing in it, and the borders of the field were covered with sweet clover. Other fields of alfalfa seeded in the neighborhood at the same time, but upon soils where sweet clover had not grown near by, were apparently complete failures, many of the plants having died and most of those still living being only a few inches high, very weak, and yellow or pale green in color.*

In order to obtain more absolute knowledge regarding this important subject, a series of pot culture experiments has been carried on under controlled conditions in the pot culture laboratory at the university. Five pots were filled with sterilized sand which was practically devoid

*Some of these observations have already been reported in the agricultural press. (See, for example, the *Breeders' Gazette*, September 9, 1903, page 391, and September 16, 1903, page 442.)

of plant food. A supply of phosphorus, potassium, and all other mineral elements necessary for the growth of plants was added to each of the five pots, care being taken to keep the sand practically free of combined nitrogen. Alfalfa seed were then planted in each of the five pots, and at the same time four of the five pots were inoculated as follows:

Pot No. 1.—Not inoculated (check pot).

Pot No. 2.—Inoculated with bacteria obtained from infected alfalfa soil.

Pot No. 3.—Inoculated with bacteria obtained from alfalfa root tubercles.

Pot No. 4.—Inoculated with bacteria obtained from infected sweet clover soil.

Pot No. 5.—Inoculated with bacteria obtained from sweet clover root tubercles.

Plate 5 clearly shows the results obtained and certainly furnishes conclusive proof that the same effect is produced upon the growth of the alfalfa whether the nitrogen-gathering bacteria used for the inoculation are obtained from alfalfa soil, from alfalfa tubercles, from sweet clover soil, or from sweet clover tubercles. It also illustrates the importance of bacteria in growing alfalfa as will be seen by comparing the four inoculated pots with the uninoculated pot, which is No. 1, on the left in each series of views. The upper view was taken when the alfalfa plants were five weeks old; the next series when they were six weeks old; the next, seven weeks old; and the lower series when they were eight weeks old, from the time of seeding.

A duplicate series of pots prepared in exactly the same manner gave similar results.

The infected alfalfa soil was obtained from a field of three-year-old alfalfa which was inoculated when first seeded, with infected alfalfa soil obtained from an old alfalfa field in Kansas. About one pound of this soil was shaken in a quart of water, the soil allowed to settle, and some of the nearly clear solution used for the inoculation of Pot No. 2. The alfalfa tubercles from which bacteria were obtained were carefully washed in distilled water to free them from adhering soil particles, and then rubbed up in distilled water, a small amount of this water being then used for the inoculation of Pot No. 3. The infected sweet clover soil was obtained from a place by the roadside where sweet clover was growing luxuriantly and well provided with root tubercles. This place was about two miles from the nearest field ever seeded to alfalfa, so far as known. A water extract from this soil was used to inoculate Pot No. 4. The bacteria from sweet clover tubercles were obtained in the same manner as those from alfalfa tubercles, and were used to inoculate Pot No. 5.

From these investigations we thus have conclusive evidence that infected sweet clover soil can be used for the inoculation of alfalfa fields,

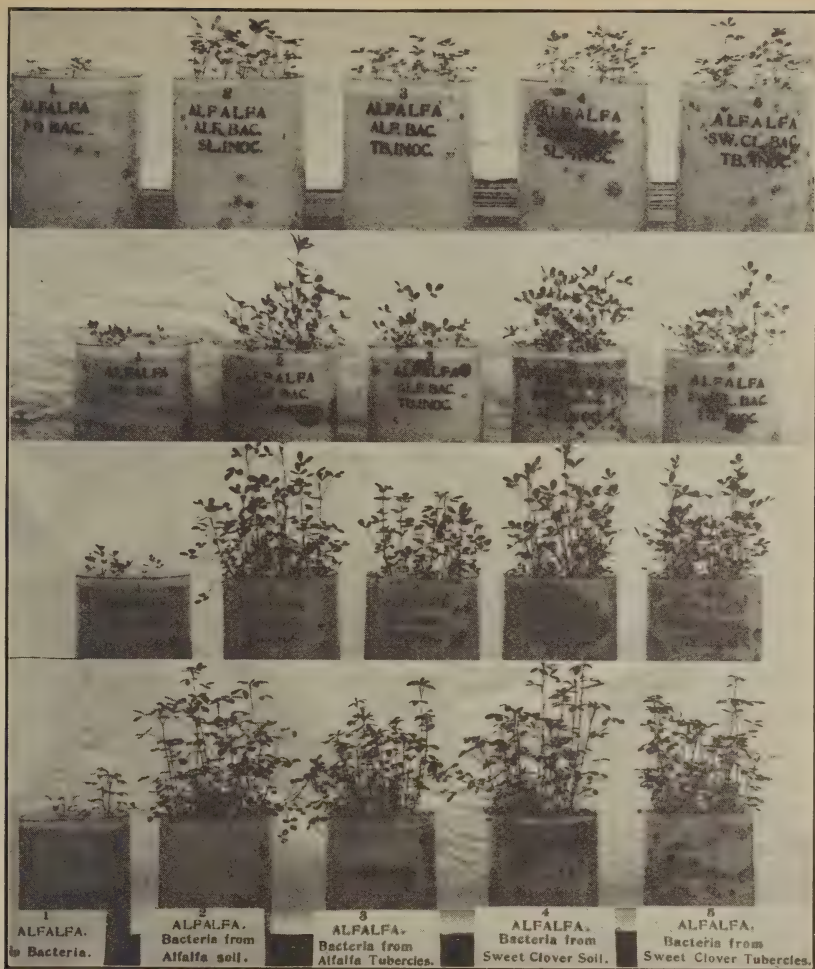


PLATE 5. ALFALFA: EFFECT OF BACTERIA FROM ALFALFA AND FROM SWEET CLOVER.

Pot 1.—No bacteria.

Pots 2 and 3.—Bacteria from alfalfa.

Pots 4 and 5.—Bacteria from sweet clover.

The four series of photographs were taken five, six, seven, and eight weeks from time of planting, respectively.

the bacteria of the two plants acting the same. The infected soil may be obtained from any place where the sweet clover is found growing with abundance of tubercles on its roots. The soil may be collected to a depth of three or four inches and scattered over the alfalfa field at the rate of 100 pounds or more to the acre. It is well to scatter the infected soil at about the time the alfalfa is seeded, and harrow it in with the alfalfa seed, although it may be applied some days or even some weeks

before seeding time, and probably it would be all right to apply the infected soil the fall before, for it is known that the bacteria will live in soil for several months, even though the soil be placed in sacks and allowed to become quite dry.

Investigations have shown that 100 pounds of thoroughly infected soil to the acre is sufficient to produce a very satisfactory inoculation within one year from the time it is applied. Of course, somewhat heavier applications may well be made if it can be done at small expense. The infected soil need not be applied with any high degree of uniformity, but special care should be taken that the higher places and watersheds are not missed in scattering it over the field. If a few square yards, or even square rods, should be missed on the slopes or lower land, it would make but little difference, as the bacteria will be washed over such places from the higher land.

After the soil becomes somewhat dry it is easily scattered by hand from the wagon or from a sack which one can carry. Sometimes it is applied by means of an end gate seeder or a fertilizer drill, or it could be spread by a manure spreader with an application of manure.

The question naturally arises whether there is not danger of getting some sweet clover seed with the infected sweet clover soil, and thus of getting sweet clover mixed with the alfalfa in the field.

In the writer's opinion there is little or nothing to fear in this matter. In the first place, the amount of sweet clover seed thus obtained would be very small, probably none at all, if one were careful to scrape off the vegetable matter, and perhaps a half inch of earth before collecting the infected soil (most of the bacteria are probably between one-half inch and six inches in depth, as most of the tubercles develop and decay between these depths); second, it is doubtful if a small amount of sweet clover hay would lessen the value of alfalfa hay in the least, for stock frequently eat small amounts of sweet clover of their own choice even when it is nearly mature, and if it is cut while still quite immature and tender it makes quite satisfactory hay, so much so that in some sections of the United States, particularly in the South, sweet clover is regularly seeded on fields and cut for hay, and it is found to be a valuable and very nutritious feed, the live stock eating it in large quantities, and with apparent relish, after they have acquired a taste for it; third, sweet clover is not known as a bad weed in the fields or meadows, even where it has been a common roadside plant for many years, and, being naturally a biennial plant, if it were cut down every five or six weeks, as we commonly cut alfalfa during the season, it would almost certainly die out after a few years while alfalfa, a perennial plant, would continue to live.

Only one instance has come to the writer's attention where alfalfa has been growing for several years with sweet clover growing in the

field or fence rows beside it. This is on the farm of Mr. D. S. Mayhew, of Mercer County, Illinois, who writes as follows regarding the matter:

"Will say that the sweet clover has made no headway in my meadow, as it did not go to seed, on account of my cutting it so often. The sweet clover got into the alfalfa in the seed when I sowed it. I do not think it will do any harm in a meadow, but I believe it would do harm in a pasture if it wasn't cut down^{*} as stock will not eat the sweet clover."

Of course if sweet clover should get into the field and persist in growing, and if it were found to injure the alfalfa appreciably or markedly, we can always resort to plowing the ground up and growing corn or other crops, thus obtaining some benefit from the leguminous crop for its fertilizing value, and at the same time completely eradicating the sweet clover, but leaving the soil well infected with alfalfa bacteria ready to serve in case alfalfa should be again seeded within a few years.

CONCLUSIONS.

In general agriculture in Illinois, whether it be grain farming or ordinary livestock farming, the growing of legumes is absolutely essential as a part of any economic system which shall maintain the fertility of the soil; and for the successful growing of legumes the presence and assistance of the proper species of nitrogen-gathering bacteria are also absolutely essential. These facts being granted, it certainly follows that when sowing any legume on land, where the same legume has never been grown before, or perhaps where it has not been successfully grown within recent years, we should always consider the matter of inoculation; and, unless there is good reason to believe that the soil has been inoculated by the washing from other higher lying land where these bacteria are known to be present or by applications of manure made from that legume, or by some other such incidental means; or unless there is evidence that the bacteria are carried with the seed in sufficient quantity to effect a satisfactory inoculation (as appears to be the case with the cowpea), then we should inoculate the soil directly with the specific bacteria required by the legume which we desire to grow.

While some Illinois soils are becoming deficient in phosphorus and in lime, especially in the southern part of the state, and while phosphorus* and ground limestone can be applied to such soils with marked benefit and profit, especially for the growing of legumes, there is abundant evidence that one of the dominant causes for the failure or unsatisfactory growth of some of our most valuable legumes, and on some soils the sole cause of failure, is the absence of the proper nitrogen-gathering bacteria.

There is no reason to believe that any of the different species of nitrogen-gathering bacteria will live in the soil for more than a few

^{*} Steamed bone meal is the most economical and satisfactory form of phosphorus for use on Illinois soils, unless ground rock phosphate (not acid phosphate) shall prove to be still more economical. Experiments to determine this are in progress.

years* in the entire absence of any legume upon which they naturally live, and the accumulating evidence strongly indicates that the bacteria which are present in places in our soils, such as the red clover bacteria, now found abundantly in many places in the state, especially in northern and central Illinois, the cowpea bacteria more common in southern Illinois, and the alfalfa or sweet clover bacteria, which are becoming prevalent in some sections—that all these have been, and are being, gradually introduced and extended almost entirely by mere chance. Of course if the wagon-wheel, which carries the mud along the road, carries with it sweet clover seed from one place to another, it may also carry the sweet clover bacteria which live on the sweet clover roots.

It now seems absurd to suppose that there were red clover bacteria in Illinois soil before red clover itself was grown on Illinois soil, unless the same bacteria live also upon some other legume which was native to our soils. There is some evidence that the vetch bacteria are native to our soil, possibly living upon the native wild vetches. At any rate, tubercles commonly develop on vetch roots without artificial inoculation. Investigations are in progress to ascertain whether the notorious failure of crimson clover in Illinois may not be due in part, at least, to the absence of the proper bacteria. (It has been stated by some writers that the bacteria of crimson clover and those of red clover are identical, but we already have some reason to doubt the accuracy of this statement.)

*Just how long the bacteria will live in a soil without a leguminous crop upon which they can feed is not definitely known. Certainly they live for two or three years, but probably not more than five or six years. Further investigation is needed to establish the length of time the different kinds of bacteria may remain in the soil under different conditions.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

BULLETIN NO. 96.

THE TESTING OF CORN FOR SEED.

By ALBERT N. HUME.



URBANA, ILLINOIS, NOVEMBER, 1904.

SUMMARY OF BULLETIN No. 96.

1. It would be possible to make a test of the vitality of every ear of corn used for seed in Illinois. Page 401
2. The testing may be done with plates of sand or with a box and blotters, or with a box and folds of canton flannel. The *method* of doing the work *is not* so important as that it be done thoroughly. Page 403
3. One man can test enough seed corn for sixty-seven acres by the use of ten hours total time. Page 412
4. It is estimated that over \$8,000,000, might have been saved to the corn growers of Illinois if all seed corn planted in 1904 had been properly tested. Page 415
5. It is reasonable to conclude that Illinois corn growers ought to be absolutely certain about the vitality of seed corn before it is planted. Page 416

THE TESTING OF CORN FOR SEED.

By ALBERT N. HUME, FIRST ASSISTANT IN CROP PRODUCTION.

We believe it would be possible for every ear of corn planted in Illinois to be tested for vitality. If an ear does not come to the desired standard, we may discard it, and plant only seed which will grow, and materially increase the stand of our corn crop the coming year. It may seem like a heavy task to germinate three or four kernels of corn from every ear in a bushel, and yet two or three evenings each week, for a few weeks, on the part of only one person, would test enough ears to plant his own crop at least. The kernels could be placed between folds of blotting-paper laid in a moist box, or moistened between two common dinner plates. It is not very difficult to keep track of the ear from which is taken each set of kernels. One kernel should be taken from the butt of the ear, at least one from the middle, and one from the tip. If all the kernels grow, the ear may reasonably be supposed to be good, otherwise it should be discarded.

Some such method as this has been employed (we are informed), by John R. Clisby, secretary of the Illinois Seed Corn Breeders' Association, for testing large quantities of seed corn. Doctor C. G. Hopkins of our University, suggested the idea to the writer. He employed it in testing every ear of seed corn which he planted on fifty acres of his own farm in southern Illinois. If these men can afford to test every ear of corn they use for seed, the same may be at least worth suggesting to farmers in general who are anxious to know what kind of corn they are going to plant.

When corn planting time arrives, the most serious question for corn growers is that of securing seed for their fields which will be certain to grow. Sometimes it is not only a difficult matter to buy corn for seed, but that which is purchased, even from the most trustworthy growers, is likely to be more or less deficient in vitality, especially under such conditions as prevailed last season. After the best seed growers have sold all their stock, they continue to receive orders which cannot be supplied. That a good deal of doubtful seed was planted last spring is shown by the following extracts from the Bloomington Weekly Pantagraph, of June 3, 1904:

"So far as this report shows, the proportion of replanted seed corn is not large, but it is large enough to attract attention and to emphasize the fact that early warnings about poor seed corn had foundation in fact.—Mr. Thomas Kuntz, living on the Thomas Janes farm near Stan-

ford, has to replant 200 acres of corn. It is reported that several others living in his neighborhood have so poor a stand that they have to replant."

"A 20-acre piece of corn on the Charles Bishop farm, 10 miles south-east of Bloomington, was being replanted, where needed, with a hoe."

"Mr. Albert Lantz, of Downs, has been replanting. Mrs. Esther Teter, of the same neighborhood, has been replanting corn."

"Mr. Oakley Stillman, of Waynesville, planted both 1903 and older corn, and the older corn came up a great deal better than last year's seed."

"Mr. Mark Gardner, of Towanda township, and Mr. James Gent, just across the line in Normal township, have been replanting corn. Mr. George Purcell, of the same neighborhood, thought he had about a half stand of corn, and was undecided whether he would replant."

"The Deer Creek correspondent writes: 'The seed corn seems to be of poor quality, as a great many farmers are planting again.'"

The low vitality of seed corn the past season was no doubt caused very largely by freezing weather while the corn was either still in the field or not sufficiently cured to withstand the low temperature. It is to be hoped that the fall of 1903 was an exceptional one in this respect, and that our recent experience may not be repeated. There is no way to guard against such falling temperatures, however. Moreover, if a season comes when our seed corn is frozen before it is put into storage, there is no way to correct the disastrous effects even with the most modern means of storage, unless we have some method of sorting out the ears which are unfit for seed. Therefore we say that the matter of selecting and testing seed is at present of foremost importance to every corn grower.

In suggesting the plan of testing each ear of seed corn, we do not mean to insist that every ear must be tested every season and in every place. We do insist, however, that this would be within easy range of possibility, as the following pages will show. Before time for planting, corn growers should test a sufficient amount of their stock of seed, ear by ear, so that they will know what they have on hand. It may or may not be necessary thus to test the entire stock, but that it would have been an extremely profitable procedure the past season for most farmers, can scarcely be doubted.

It is not sufficient to accept the warrant of the dealer from whom the seed is purchased, however trustworthy he may be. It is not possible for those who handle seed on the largest scale to give the closest attention to its quality. The following devices for testing are suggested as being obtainable for the general farmer.

METHODS OF TESTING.

There are several methods of testing corn, all of which depend upon the same principle, namely, that of supplying sufficient moisture and warmth to the kernels to cause them to sprout. The traditional ways of determining the quality of seeds, such as floating them in water, or heating them until they pop, or breaking them and noting the fracture, or cutting them and noting the appearance of the inside, cannot be called tests, although it must be granted that by practice some corn growers have become fairly expert in telling whether or not a given sample of corn will grow. Such methods are not only less accurate, but if carefully performed require as much or more time than need be taken to make a germination test.

One of the best and simplest ways of sprouting seed is to take a common dinner plate and fill it nearly full of sand. The sand should be as clean and white as possible. Such sand will be less likely to mould than that which has much organic matter in it. This makes it much more desirable for use in testing, for moulds interfere with the germination of the corn. After the sand is placed on the plate, it should be moistened. This can best be done with a small sprinkler, but if one is not at hand, the water may be poured carefully out of any small vessel or sprinkled with the hand. After sprinkling the water on the sand, it is well to mix the sand with the fingers until it is all equally moist. Do not saturate the sand with water. Special caution is necessary in this respect, for if the sand is too wet, the corn will fail to germinate for lack of air. Numerous failures have been reported in testing corn on plates of sand, the most of which probably resulted from having the sand too wet.

Having the sand properly placed and moistened, the kernels to be tested should be pressed into the sand, small end down, in order as they are taken from the ear. While taking the kernels from the ear, hold it in the left hand and remove with a pocket-knife or a pair of small, strong tweezers, a kernel two inches from the butt of the ear. A little practice will make it easy to remove a kernel with the knife and hold it between the thumb and the knife blade until it is put in place in the sand. Then turn the ear one-fourth around and take another kernel in the same manner, say two inches nearer the tip; then turn the ear the same distance again and take another kernel two inches nearer the tip. For the fourth kernel, turn the ear again one-fourth around and take the kernel about two inches from the tip. Four kernels is a large enough number to take from one ear for practical work. If they are properly taken, they represent both ends and all sides of the ear, so far as vitality is concerned. The four kernels from each ear must be placed in a separate group, and it is best that the group be marked or numbered to corre-

spond with the number of the ear from whence the kernels were taken. (Plate 1, Fig. 1.) For this plan, it is necessary that the ears be placed in regular order, as the kernels are removed from them. A good device for arranging the ears in regular order is shown in Plate 2. The frame from which the photograph was taken is in use at the Agricultural Experiment Station.

It does not take a mechanic of very great skill to make the frame. It will be noted from Plate 2 that the ends of the ears when they are put into place, rest upon small iron rods, and that the ears are kept from rolling sidewise by two small wires on each side. It would be possible to make the divisions for the separate ears out of lumber, but the wires are lighter in weight and cheaper. Moreover, they do not prevent the circulation of air between the ears of corn, which in some cases is an advantage, and they do not furnish a harbor for mice and rats.

THE GERMINATING ROOM.

After the kernels of corn are all placed as described above, they should be covered by turning a second plate over them to prevent too rapid evaporation of the moisture from the sand. (Plate 1, Fig. 2.) They may then be left in a warm temperature to sprout. As fast as the kernels are well germinated, they should be removed from the sand, and a careful record taken of the number which have sprouted. It has been proved by experiment that the best temperature for germinating corn is 77 degrees F. This is only a little higher than the temperature of an ordinary living-room. More harm will result from a considerable decrease of temperature than from a slight increase.

On the average farm it is not necessary to construct a special room for germinating. Usually the plates of corn will germinate well if put beside a stove, taking care that they do not get too hot. The plates must be inspected each day after they are put into the germinating room, and if the sand is becoming dry, add a little water. The amount to be put on must be determined by practice, for it will vary with the kind of sand used and with the humidity of the room. If one is fortunate enough to have furnace heat in the cellar, he will probably have a place near the furnace where the heat will be about right for germinating corn. Such heat was utilized by Dr. C. G. Hopkins, of the University of Illinois, in testing the corn for his own farm in southern Illinois, with entirely satisfactory results.

Plate 4 shows a sort of incubator which served as a germinating chamber at the seed house of Mr. John R. Clisby. The heat was furnished from below by a gasoline stove. A tank of water was set on the gasoline stove and the rising steam distributed the heat and prevented

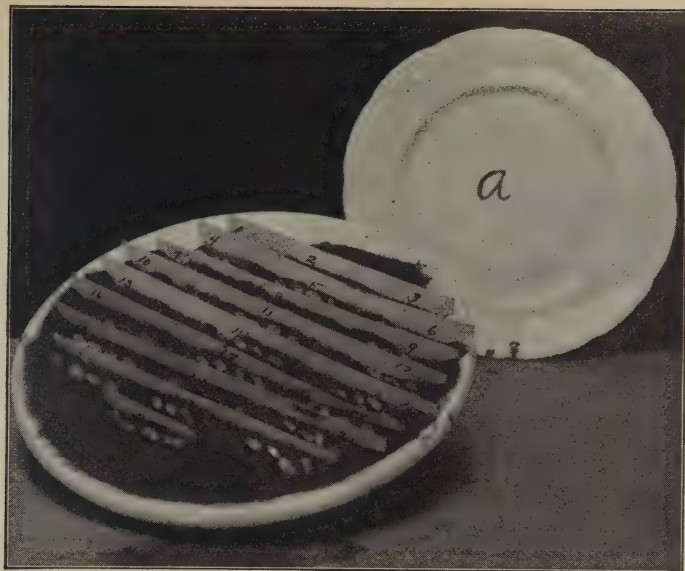


FIG. 1.

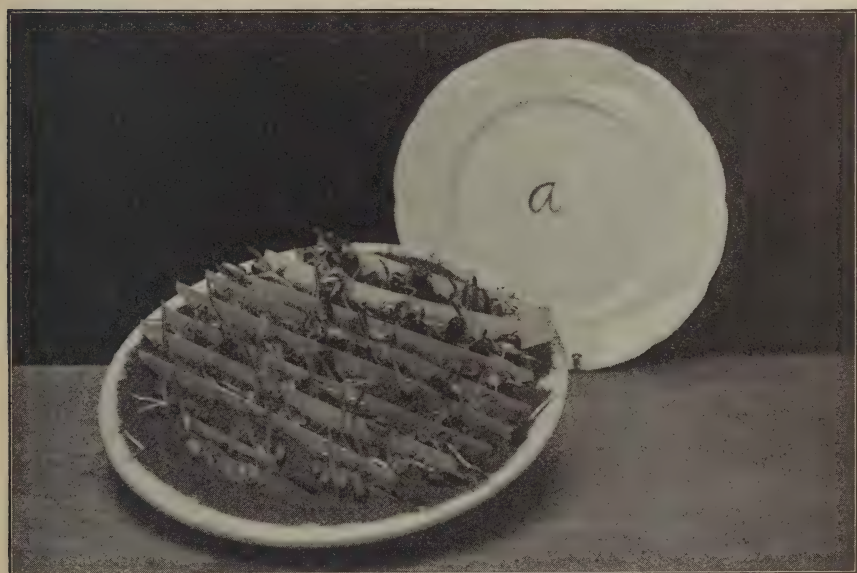


FIG. 2.

PLATE 1. FIG. 1 SHOWS GROUPS OF KERNELS FROM SINGLE EARS, READY TO BE PUT INTO THE GERMINATING ROOM.

FIG. 2. THE SAME KERNELS, GERMINATED, READY TO COUNT.



PLATE 2. SHOWS THE DEVICE FOR ARRANGING EARS IN REGULAR ORDER AFTER HAVING KERNELS REMOVED.

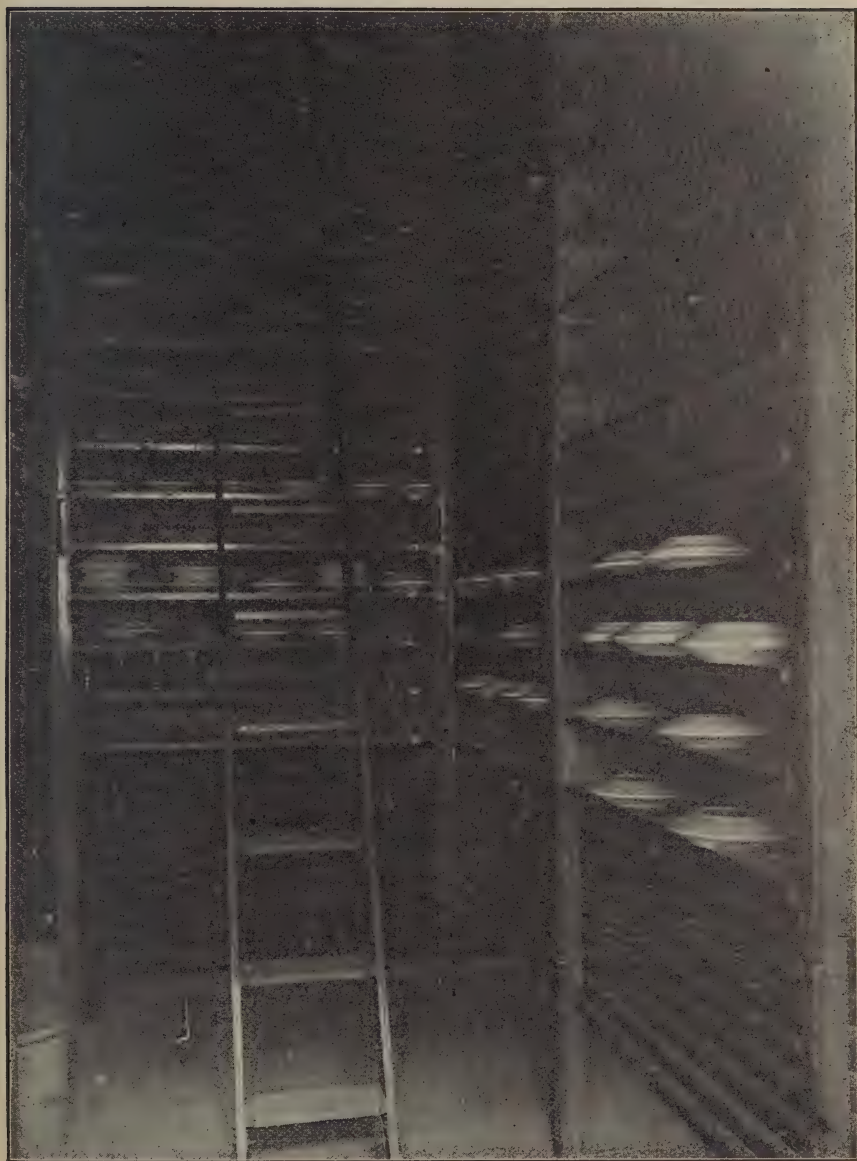


PLATE 3. THE GERMINATING ROOM NOW IN USE AT THE EXPERIMENT STATION.

the too rapid drying of the corn kernels. The arrangement was not entirely satisfactory, inasmuch as the steam warped the lumber of which the frame was made. An ordinary incubator, such as is used for hatching eggs, would doubtless answer the purpose of a germinating chamber.*

TESTING WITH PLATES AND SAND.

The method of using the plates of sand for germinating corn is very practicable in that any one can use it without purchasing any new material. Dinner plates are at hand on any farm, and sand may usually be had from the roadway or river bottom. But where there is much testing to do the method is inconvenient, and in some cases unprofitable, from the fact that it takes too much time. Time is lost in filling the plates with sand and in gauging the proper amount of moisture, when it must be renewed from time to time. The actual time used in testing several lots of corn by this method is shown in Table 2.

TESTING WITH BOX AND CLOTH.

One of the quickest and most convenient devices for making germination tests is that commonly known as the Geneva Tester, so called because it was first used by Professor Goff at the Geneva Station in New York. (Plate 5.) This apparatus consists of a water-tight box across which are extended folds of canton flannel. These folds are suspended from wires, as shown in Plate 5, and can be removed to dry when not in use. The box must be filled to the depth of about an inch with water, so that the folds of canton flannel will hang down enough to touch the water, and thus be moistened by capillarity. The box should be about 12 by 24 inches and 4 or 5 inches deep. It may be made of wood, galvanized iron, tin, or copper, and the wires can be cut from ordinary smooth galvanized fence wire. When kernels of corn are to be tested in this germinating apparatus, they are removed from the ears as described above, placed between the folds, in regular order (Plate 5) and the folds closed together. If it is thought best, the groups of kernels from the separate ears may be numbered with slips of paper, as shown in Plate 5. This numbering will not be absolutely necessary if proper care is used to have the groups of kernels correspond to the ears of corn from whence they came. After the kernels are put in place, the

*The germinating room in use at the Experiment Station is shown in Plate 3. Around the lower part of the wall are coils of steam pipes by which the room may be kept as nearly as possible at the desired temperature. Shelves are arranged around the three sides of the room, upon which are set the plates of corn for germination.

The improved standard germinating chamber, used by the Department of Agriculture, is described in Circular No. 34, and Circular No. 34 (revised) of the Office of Experiment Stations, U. S. Department of Agriculture, Washington, D. C.



FIG. 1.

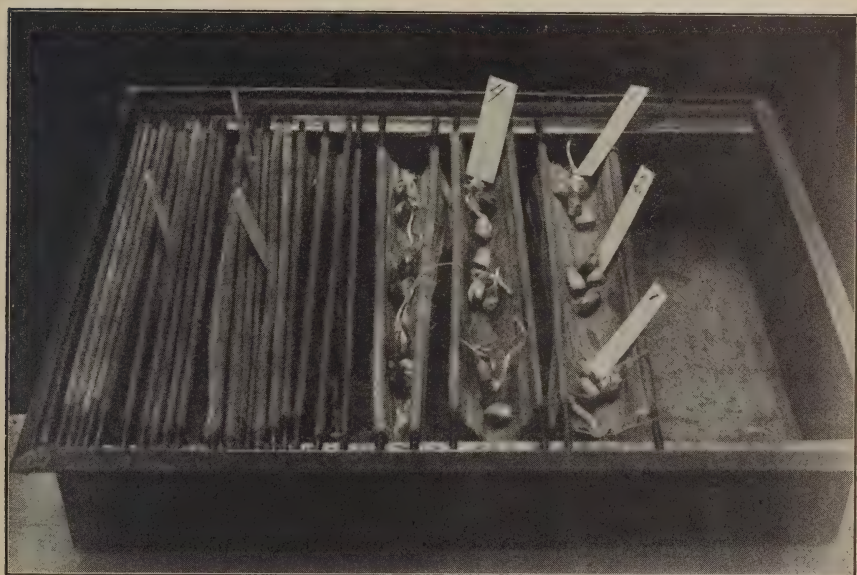


FIG. 2.

PLATE 5. FIG. 1 SHOWS GROUPS OF KERNELS FROM SINGLE EARS, READY TO BE PLACED IN THE GERMINATING ROOM.

FIG. 2. SHOWS THE SAME KERNELS, SPROUTED.



PLATE 4. AN INCUBATOR USED FOR GERMINATING CORN. A GASOLINE STOVE PROVIDES SOURCE OF HEAT.

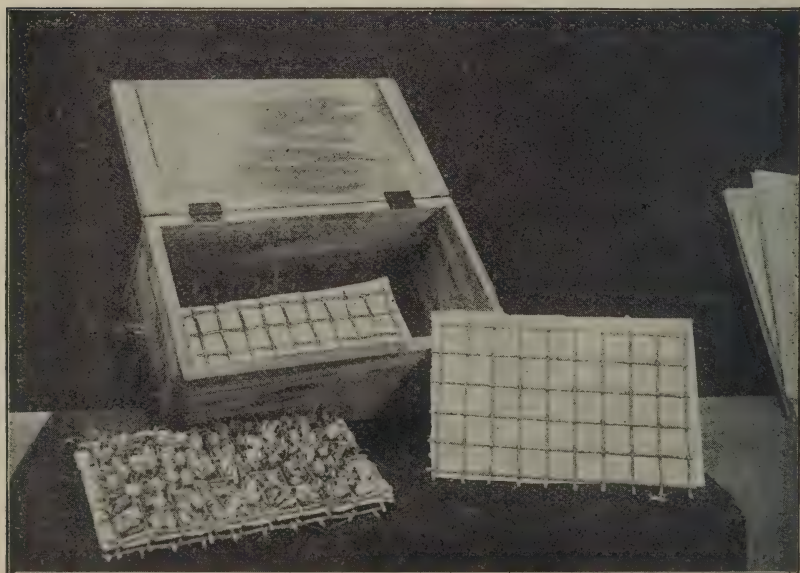


PLATE 6. SHOWING THE WOODEN BOX, BLOTTERING PAPERS, WIRE GAUZE, AND GROUP OF KERNELS ALREADY SPROUTED.

folds are drawn together at the top, the lid closed upon the box, and the apparatus left until the kernels germinate. When put into this box, the kernels will not usually suffer for moisture during the length of time of one test. This is one of the advantages of the Geneva Tester over the plate of sand where the moisture may need renewing each day, or even oftener. The folds are easily opened when it is necessary to inspect the kernels to count the number which have germinated. Some care is necessary in lifting the tester, that the groups of kernels be not jarred from their places.

TESTING WITH BOX AND BLOTTERS.

Another plan is to use a small box, with layers of moistened blotting-paper inside. (Plate 6.) This device consists first of a small box, say a foot long, six inches wide, and five inches deep. The bottom of the box should be made water-tight; if necessary, the cracks may be stopped with white lead or strips of cloth or asbestos. The kernels of corn are kept moist by putting water into the box to a depth of one-half inch more or less. Something must be laid in the box to hold the first blotter up out of the water. Small sticks laid crosswise of the box will answer this purpose.

The blotting papers should be moistened as they are placed in the box. When the first blotter is laid in, either small sticks or wire cloth are put down on top of it to mark the spaces for the separate groups of kernels. These spaces must correspond to the spaces in the frame where the ears of corn are placed (Plate 2). After one layer of blotting-paper is covered with the kernels, another similar layer may be put down on top of the first, and so on until the box is filled, or until the desired amount of corn has been put in.

Like the plate and sand method and the wooden box Geneva Tester, this device is easy to use on the ordinary farm because it does not necessitate the buying of any expensive apparatus or material. The box shown in Plate 6 was made to order, but it would be possible to substitute any ordinary box which is reasonably close at the joints. If small sticks are substituted for the wire gauze, it will only be necessary to purchase the pieces of blotting-paper, which can be secured at a merely nominal cost of almost any printer or stationer. Of course the wooden box will sometimes warp and begin to leak, making it somewhat difficult to keep the blotters from becoming too dry. Where it is desired to use a tester for any large amount of work, it is usually best to have the box made of copper.

We have gone into the matter of explaining the devices for testing seed corn at some length from the practical standpoint, in the hope that the greatest number of corn growers will arrange to test seed by one of the methods. The method of doing the work is not of such paramount importance as that it be done, and done thoroughly.

In advocating the testing, when necessary, of every ear of corn intended for seed, we have been met with the objection that "it takes too much time." We have therefore made some careful computations along this line. In Table 1 we have recorded the time in minutes used in testing each of nine one-bushel lots of corn. Column 1 gives the number of the lot, column 2, the number of the ears in the measured bushel, and column 3, the total time used in testing four kernels from each ear, in the Geneva Tester, with which we have been able so far to do our quickest work in testing.

TABLE 1.

Number of lot.	Number of ears in bushel tested.	Total time used in testing.
1	100	45 minutes.
2	98	44 minutes.
3	75	34 minutes.
4	116	56 minutes.
5	80	48 minutes.
6	77	38 minutes.
7	95	42 minutes.
8	96	46 minutes.
9	126	48 minutes.

Total time for 9 bushels, 401 minutes.

Average time for 1 bushel, 45 minutes.

From the above table, it will be seen that the total time used in testing 9 bushels of corn of various sized ears was 401 minutes. It takes longer to test a bushel of small ears than a bushel of large ones, but the average time per bushel is 45 minutes. At this rate, counting only 5 acres to one bushel of seed, one man, in 10 hours' total time, can test every ear of seed corn required to plant 67 acres. Of course the work must be done before planting time. It is suggested that winter evenings might profitably be employed in this way, but if the work is not done in the evenings, let it be done by daylight as part of the regular work. At all events, do not permit it to be overlooked, especially when we have such seed corn as much of that planted in 1904.

It has already been suggested that it takes more time to test corn in plates of sand than in the Geneva apparatus. Table 2 is offered to show the time used in testing by this method.

TABLE 2.

Number of lot.	Number of ears tested in measured bushel.	Time required for testing in sand.
29	100	80 minutes.
30	98	85 minutes.
31	75	63 minutes.
32	88	75 minutes.
33	92	72 minutes.

Total time required to test 5 bushels, 375 minutes.

Average time required to test 1 bushel, 75 minutes.

As seen by the above, the average time for testing in sand is 75 minutes per bushel as against 45 minutes per bushel with the Geneva Tester. It is apparent that any one who has any amount of testing to do, can well afford to make a Geneva Tester or have one made, rather than use sand.

It is sometimes urged that one who has had sufficient practice can select seed corn which will grow, simply by inspecting it, and that testing is unnecessary.

There are many persons who can tell, with some accuracy, by simple examination, whether or not corn will grow, but we do not believe that inspection can be so accurate as testing. Moreover, the time used in carefully inspecting each ear in a given lot of corn is usually as great or greater than the time used in testing the same ears. The time required depends much upon the care with which the work is done. If four kernels are taken from each ear of corn and each kernel examined carefully and the germ inspected, it will require more time than it will to test the kernels in the Geneva apparatus. The average time used at the Station for inspecting thirteen bushels of seed corn with reasonable care, was 31 minutes per bushel. With two lots, when four kernels were removed from each ear and carefully examined, the average time required was 44 minutes per bushel. The average time for testing these same two lots in the Geneva Tester was 32 minutes per bushel. Even when the time element is taken into consideration, the evidence is all in favor of carefully tested seed for the corn grower, as opposed to that selected mechanically.

The following table shows the results which were actually attained with 37 different lots of seed corn.

Eighteen of these lots of corn came to the Experiment Station from progressive farmers, and nineteen came from the most trustworthy corn specialists to be found. In the table given, column 1 indicates simply the number of the lot of corn tested. Column 2 gives the number of ears in that particular lot, and column 3 indicates the percent of the corn, taken just as it came to the Station, which germinated. This test was simply a composite one. Three kernels were taken from each ear, one

from the butt, one from the middle, and one from the tip. After three kernels were thus taken from every ear in the entire lot, they were mixed together, and 100 of them were selected at random. These 100 kernels were germinated and the resulting percent was put into column 3. After this composite test was made, every ear in each lot was tested, by taking four kernels from an ear and germinating them in sand. In case any one of the four kernels did not grow, the ear from which it came was discarded as unfit for seed. The number of ears thus discarded is recorded in column 4. The remainder were reserved as being good for seed. Then, in order to determine whether such testing really accomplishes the desired object, composite tests were made of the "good corn," which was reserved for seed, and of the "poor corn," which was discarded. The percents for the various lots as derived from these tests are recorded in columns 5 and 6.

TABLE 3.

No. of test.	Number of ears tested.	Composite test of all ears.	Number of ears discarded.	Percent of germination after testing	
				Good corn.	Poor corn.
1	41	91.0	11	98.9	82.0
2	439	82.5	144	97.0	68.0
3	81	87.0	12	99.0	72.2
4	371	84.0	95	95.0	55.0
5	34	78.0	18	97.9	72.2
6	330	95.0	51	98.0	80.0
7	433	94.0	38	100.0	72.0
8	414	83.0	124	95.0	63.0
9	552	77.0	299	86.0	67.0
10	389	97.0	31	100.0	85.5
11	88	96.0	14	97.0	80.9
12	80	82.0	18	94.0	70.8
13	298	93.0	44	98.0	71.0
14	89	93.0	10	97.0	66.6
15	60	84.0	22	96.0	77.0
16	18	88.8	5	89.7	66.6
17	43	83.0	20	90.0	40.0
18	451	96.0	33	99.0	68.0
19	332	93.0	88	98.0	81.0
20	456	62.0	295	93.0	30.0
21	278	74.0	164	86.0	36.0
22	109	87.0	21	97.0	71.4
23	45	83.0	17	97.6	75.0
24	40	51.0	28	97.2	52.3
25	73	89.0	20	95.0	48.0
26	144	92.0	36	95.0	81.0
27	100	93.0	25	97.0	69.8
28	98	91.0	18	95.0	68.9
29	75	94.0	17	95.0	76.0
30	88	87.0	26	96.0	66.6
31	92	93.0	13	93.0	77.0
32	116	90.0	39	93.0	70.0
33	80	86.0	34	83.0	75.0
34	77	68.0	41	74.0	42.0
35	95	74.0	54	90.0	57.0
36	96	64.0	63	80.0	51.0
37	126	97.0	20	96.0	60.3
Averages,		85.19		94.00	66.11

It will be observed that the percent of germination of the "good corn" in column 5, is higher in every instance than the percent of germination of the "poor corn," in column 6; also that there are only two instances—that of test number 33, composed of 80 ears, and that of test number 37, composed of 126 ears—in which the percent of germination for the good corn is not as high or higher than that of the composite sample from which it came. This evidence therefore practically all goes to indicate that the plan is effective. In other words, having given a number of ears of seed corn, *it is possible to determine with accuracy which of those ears have the highest average percent of germinable kernels.*

The average of all the tests of "good corn" in column 5 is 94.00 percent. The average of the composite tests of the lots of corn from whence those good ears were taken, is 85.19 percent. The original lots were made up of seed corn, which was carefully selected by ordinary methods before it came to the Agricultural Experiment Station. The difference between 94.00 and 85.19 is 8.81 percent, in favor of the "good corn," which is clearly attributable to the fact that every ear was tested and only the "good ones" reserved. That this difference is correct is further attested by noticing the average percent of the "poor" lots of corn in column 6, which is 66.11. Evidently from this, no mistake was made in the kind of ears discarded.

It is fair to assume, according to the above figures, that the seed corn planted in Illinois during the spring of 1904, might have been at least 8.81 percent better than it was. Although it does not follow absolutely, it is not far from correct to reason that the crop is 8.81 percent lighter than it might have been, had the best seed attainable been used. This is a conservative estimate considering that the original lots of corn above were probably better than the average seed corn planted in Illinois in 1904.

Granting, then, that 8.81 percent of the seed planted failed to grow and that there were 1,000,000 bushels of corn used for seed in Illinois, the amount of corn planted which did not grow was 88,100 bushels. Valuing it at \$2.00 per bushel, it represented a dead loss of \$176,200. This amount alone would pay for testing practically every ear of corn planted in Illinois, counting labor at \$1.50 a day. The great loss, however, consists in the shortage of the crop due to this poor seed. The valuation of the corn crop in Illinois, as given in the year book of the Department of Agriculture for the year 1903, was \$95,000,000. Counting the proportionate loss therefore, which might have been prevented by proper testing of seed corn, we have \$8,369,500. The data herein presented certainly justifies the conclusion that such a sum could have been saved by Illinois corn growers the past year by properly testing seed.

To bring the matter as closely home as possible to the individual farmer, suppose that he raises 80 acres of corn, and that his normal yield is 60 bushels per acre, giving a total of 4,800 bushels. His average loss this year was 8.81 percent of that amount, or 422.88 bushels. Valuing this at 40 cents a bushel, we have a loss of \$169.15 due to the use of untested seed. This amount would pay the necessary wages for testing every ear of seed corn which would be used on 7,555 acres of land, counting the wages at \$1.50 a day. These figures ought to appeal not so much to our seed dealers as to farmers and corn growers. They are the people directly interested.

Having determined the data above, it is not unreasonable to assert that every corn grower ought to know beyond any peradventure, just what kind of seed corn he pours into his planter boxes at planting time. We do not mean to urge anything unreasonable, and we are not doing so. If we were to test say 1,000 ears of seed corn from a seed house and found them to grow perfectly, we would be ready to admit that the next 1,000 ears were reasonably safe for seed, providing they were the same kind of ears, kept under the same conditions as the first 1,000 had been; but we would not take too much for granted.

The object toward which we are all striving, is that agriculture be made an exact science. The testing of each ear of seed corn, whenever necessary, will certainly be a considerable stride in that direction.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

BULLETIN NO. 97.

MARKET CLASSES AND GRADES OF
SWINE.

By WILLIAM DIETRICH.



URBANA, NOVEMBER, 1904.

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MARKET CLASSES AND GRADES OF SWINE.

By WILLIAM DIETRICH, ASSISTANT IN SWINE HUSBANDRY.

INTRODUCTION.

In selling hogs to the local buyer or shipper, the farmer is very often at a decided disadvantage because he cannot interpret market reports to the full extent of their meaning, and therefore either does not get what his hogs are worth or loses a sale by asking too much for them. Believing that the producer of swine can be helped to a better understanding of the market end of the business, it was thought that an attempt to explain how swine are classified and graded on the Chicago and other markets would be of benefit to the average farmer. The regular shipper who visits the market frequently and the large farmer who accompanies his stock to market have excellent opportunities to become acquainted with stockyards expressions, and therefore the market reports as they refer to the various classes and grades of swine. It is primarily for the benefit of those who do not have this opportunity that this work was undertaken.

The necessity of an explanation of the classification is clearly evident. The very great difficulties, however, of such an undertaking are not so evident. The weight, condition, and quality of hogs coming to the market vary between wide limits, and, in general, make up markedly different classes and grades. Owing to the varying opinions held by different people who have to do with the handling of hogs on the market, and the activity of the market for certain classes compared with the dullness of the market for other classes, the limits of these different classes are somewhat variable. The boundary lines may be shifted one way or the other, depending on the activity of the market for one class and the dullness of the market for the other class, e. g., light hogs may be in great demand, but not very plentiful, and heavy hogs may be plentiful, but not in very great demand; then the boundary line between light and heavy hogs would be slightly raised so that the demand in the light-hog class could be filled with hogs from the lower limits of the heavy-hog class. The difficulties of the task are further augmented in describing animals of the various classes with varying condition and quality so that they are clear to the reader. It is a comparatively simple matter to bring out animals to represent certain types and to illustrate with them the classes and grades to which they belong. But to describe on paper these concrete objects with such abstract differences as quality,

without the object itself, is by no means an easy task. On account of the restlessness and lowness to the ground of swine, it is difficult to secure good photographs of them, but having secured them, they are very helpful to familiarize the reader with the different classes and grades.

Another difficulty that confronts one is the lack of uniformity in terms used in different market reports. Some of the terms thus used are not characteristic of what the names represent, and others are too broad in scope.

In an effort to present the subject so as to conform as nearly as possible to the true relation of things and in such a manner that it can be understood by the average reader, the classification given in the following pages has been evolved. It must not be understood, however, that this is simply a theoretical classification. It is in fact the real classification used in the Chicago and other stockyards, although not strictly observed in market reports or absolutely followed in practice by buyers and salesmen. Very often it is much abridged without any inconvenience to those familiar to the trade.

In small market centers the classification is not so complete, because the market demands are not so exacting nor the supply so abundant. As far, however, as the classification is carried out in American hog markets it is in accord with the classification herein given.

This bulletin is the result of a personal and extensive investigation on the Chicago and other markets, both in the United States and Canada, where every possible courtesy was extended by the packers, stockyards officials, government inspectors, and especially by buyers, speculators, and commission men. Grateful acknowledgment is gladly made for assistance rendered by them in the preparation of this bulletin.

All but two of the cuts presented herein were made from photographs taken expressly for this bulletin, and no time or expense was spared to obtain photographs which should be both clear and illustrative of what they represent.

Before taking up the discussion of the market classification it is necessary, in order to get a better conception of the subject in hand, to take up a general consideration of the hog of the United States leading up to the development of the

FAT OR LARD HOG.

To show the importance of the United States in the swine industry of the world, and thereby its influence in developing type, it is only necessary to state that it produces two-fifths of all the hogs in the world. In round numbers, according to the latest statistics obtainable, the United States has 47,000,000 hogs; Germany, 17,000,000; Russia, 11,000,000; Hungary, 7,000,000; Canada, 3,000,000; Spain, 2,000,000;

Roumania, 2,000,000; Poland, Belgium, Denmark, Australasia, and the Netherlands, each 1,000,000. All other countries, together with those above enumerated, have enough to make 117,000,000.

As to the distribution of hogs in the United States, we find that in the year 1901-'02, there were packed in the western states, including Ohio, Kentucky, and the states to the west, 25,411,676 hogs. During the same year there were packed in the eastern states, including New York, Pennsylvania, and all states to the east, 2,749,000 hogs. Considering that Chicago alone ships 1,000,000 hogs to the east annually, it is very evident that the states of the Mississippi Valley play a very important part in the swine-growing industry of the world. The type of hog produced here is familiar to all stockmen of the United States. Unlike the bacon hog of England, Denmark, and Canada, the most valuable parts of this animal are the hams, back, and shoulders, consequently these parts are developed at the expense of the sides, and the result is a hog that is diametrically opposite to the above mentioned bacon hog, viz., one that has a broad back, wide and full hams and shoulders, also a heavy neck and jowls, with a large proportion of external as well as internal fat.

The question that naturally presents itself in this connection is, why is there such a difference between these different types of hogs when they are all used for meat production? This question is all the more striking when we stop to consider that all the breeds of beef cattle and mutton sheep in all the principal countries of the world are practically of the same form. If not yet of precisely the same form, they are all being developed toward the same ideal. It is true that there is a great difference between beef cattle and dairy cattle, but they serve different purposes. In one instance, the production of meat is of primary importance; in the other, milk and butter are produced at the expense of meat. Considering that the fat or lard hog furnishes fat in the form of lard, and the dairy cow furnishes fat in the form of butter, there might be a slight comparison between the two. But on the other hand, the fat or lard hog is grown primarily for the meat produced from his carcass, consequently both in this respect and in his form, the fat or lard hog resembles the beef steer. Then why the difference between the two above mentioned types of hogs?

Most of the hogs of the United States as shown above are grown in the corn belt, consequently this section of the country has taken the lead in the development of swine of the fat or lard hog type, and has determined their characteristics. When the United States was settled, swine, of course, were brought over from Europe, but conditions here, and especially in the corn belt, were very different, and the character of the hog was changed to meet the demand as it developed under the different conditions.

There are three principal reasons for the development of the fat or lard hog:

1. The abundance and relatively low price of corn.
2. The home demand for cured meats.
3. The foreign demand for cheap meats.

(1) Corn is a plant native to America, and in the corn belt can be produced with much less cost than can any of the other grains. It is very natural then that it should be used almost exclusively as a feed for swine. It is a feed that is comparatively rich in carbohydrates and much lacking in protein. Carbohydrates are used in the animal body for building up fat and to furnish the fuel that is used in the production of physical energy. Protein is that part of a food material that is rich in nitrogen and is used principally to build up muscle or lean meat. Feeds such as middlings, peas, skim milk, etc., are rich in this constituent. Now, since corn is the principal source of feed for swine in the United States, it is only the natural consequence that its hogs are of the fat or lard hog type.

(2) In the earlier history of the United States, very few, if any, of the frontier sections had railroad facilities, so could not import fresh meats; neither had they facilities for local production of meats. Then, again, these places, and especially the lumber camps, used a great deal of meat, and it had to be of such a nature that it could be hauled long distances on wagons and be capable of long storage after reaching its destination. The most satisfactory meat for this purpose was mess pork. There are two reasons why fat salt pork was better than lean salt pork. (a) Fat pork does not become so salty on being pickled as does lean pork. It is not so thoroughly penetrated by the salt, therefore is more palatable after long storage than is lean pork, which also requires a larger quantity of salt, and is not so well preserved as is the fat pork. (b) Fat pork was better both from the employer's and from the consumer's point of view, because on account of its fatty nature, it contains two and one-fourth times as much energy per unit of weight as does lean pork, therefore making a cheaper article on the bill of fare, also furnishing sufficient energy to the laborer who was toiling hard in cold winter weather.

(3) There was a foreign demand by the poorer class of people for cheaper meats than could be supplied by their high priced bacon industry. This cheaper meat could be supplied in the form of fat pork made from low priced corn, and at the same time could be furnished at a profit.

From these various causes it is clearly evident that the fat or lard hog of the United States was produced not only because he could be produced more cheaply than the bacon hog, but also because there was a demand for just such a hog.

The following is the classification of swine as used on the principal markets:

CLASSES.	SUBCLASSES.	GRADES.
PRIME HEAVY HOGS, 350-500 lb.		PRIME.
BUTCHER HOGS, 180-350 lb.	HEAVY BUTCHERS, 280-350 lb.	PRIME.
		GOOD.
	MEDIUM BUTCHERS, 220-280 lb. LIGHT BUTCHERS, 180-220 lb.	PRIME. GOOD. COMMON.
PACKING HOGS, 200-500 lb.	HEAVY PACKING, 300-500 lb.	GOOD.
	MEDIUM PACKING, 250-300 lb.	COMMON.
	MIXED PACKING, 200-280 lb.	INFERIOR.
LIGHT HOGS, 125-220 lb.	BACON. {	CHOICE.
		LIGHT.
		FAT.
	U. S., 155-195 lb.	CHOICE.
		GOOD.
		COMMON.
	LIGHT MIXED, 150-220 lb.	GOOD. COMMON. INFERIOR.
Pigs, 60-125 lb.		GOOD.
		GOOD.
		COMMON.
ROUGHs.		
STAGs.		
BOARs.		

MISCELLANEOUS.

ROASTING PIGS, 15-30 lb.
FEEDERS.
GOVERNMENTS.
PEN HOLDERS.
DEAD HOGS.

PRIME HEAVY HOGS.

By the term "prime heavy hogs," is meant a prime heavy fat-back hog, weighing from 350 to 500 pounds, the extreme of the fat or lard hog type. Plate 1, page 424. (For meaning of prime, see discussion under "Butcher Hogs," page 425.)

With the tendencies of the market working toward the lighter hogs, there are not very many of these heavy hogs at present coming to market; however, there are still enough to make a market class. The fat meat of these hogs is classified separately, and finds a market in Germany, France, and in some parts of Spanish America. Such cuts as "clear backs" and "clear bellies," which are composed of the clear fat without any admixture of lean meat, are made from hogs of this class.



PLATE I. PRIME HEAVY HOSS

BUTCHER HOGS.

Butcher hogs as a class are principally barrows. Other things being equal, barrows sell more readily and at better prices than do sows. In a drove of butcher hogs there may be present a few good sows without detracting from the value of the drove. Good young sows, as a rule, are kept on the farm for breeding purposes, and poor young sows and old sows will not take on the finish required in the butcher hog class.

Butcher hogs are commonly used for the fresh meat trade. They may be slaughtered and consumed at home, may be shipped and slaughtered in the east, may be slaughtered locally and the meat consumed locally, and may be shipped east, or even to foreign countries. About 25 percent of the hogs coming to the Chicago market annually are of this class. They range in age, with good care and heavy feeding, from about six months for the light butchers to one year for the heavy butchers. With less intensive feeding the age will be greater for hogs of the various weights.

The class of butcher hogs is subdivided into three subclasses, as follows:

Heavy butchers, 280-350 lb.

Medium butchers, 220-280 lb.

Light butchers, 180-220 lb.

Except in weight, these three subdivisions are practically the same.

Hogs of this class are graded on the market as follows:

Prime heavy butchers, plate 2, page 426.

Good heavy butchers, plate 3, page 428.

Prime medium butchers, plate 4, page 429.

Good medium butchers, plate 5, page 430.

Common medium butchers, plate 6, page 430.

Prime light butchers, plate 7, page 431.

Good light butchers, plate 8, page 431.

Common light butchers, plate 9, page 432.

PRIME BUTCHERS.

Hogs that will grade as prime butchers, either heavy, medium, or light, must be perfect in quality, ideal in form, and must show much evidence of ripeness in condition as well as maturity.

Prime.—The term "prime" in a general way means the best of the class, but in a more specific way in stockyards' vernacular, it has a meaning of its own. To grade as prime, a hog must show marked evidence of ripeness and maturity. The two must go hand in hand. A hog may be mature without having been fed so as to show that bloom of condition that is necessary for a prime hog, or he may have been as well fed as possible and not be sufficiently mature; consequently he would not grade



PLATE 2 PRIME HEAVY BUTCHERS

as prime. The high state of finish required for a hog of this grade is brought about by liberal grain feeding to maturity. Maturity in general means that condition at which development is complete. In a more specific sense in the realm of swine feeding it may be given an additional meaning, viz., that stage in the process of feeding where growth ceases under a given system of feeding and the animal takes on the form and appearance as well as the high state of finish of an ordinarily well-fed mature animal. This may be at different ages and weights, thus giving us prime heavy hogs and prime, heavy, medium, and light butchers, ranging in weight from 500 down to 200 pounds.

Quality.—By quality is meant the characteristic that is indicated by a medium sized, fine, clean-cut head without any surplus fat or wrinkles of skin; medium sized ears of fine texture; hair that is fine, straight, and silky, and lies close to the body; skin that is smooth, pliable, and free from wrinkles; tail that is smooth, nicely tapering, and not too large; bone that is fine, firm, and free from undue coarseness at the joints as indicated in the legs; shoulders that in the case of boars have not too large development of shields; and by a symmetrical, smooth development throughout the entire body. In short, such points of refinement in form and features as are characteristic of well-bred swine.

Form.—The form of a prime butcher hog is that of an ideal fat or lard hog, viz., broad back, wide and well-filled hams and shoulders, short, heavy neck, heavy jowls, and short legs. The hog must have these parts well developed, and at the same time be symmetrical, smooth, and compact. Together with this form there must be an indication of quality, such as goes only with good breeding and good feeding.

Condition.—Condition is a greater factor than either form or quality in determining the grade to which a fat hog belongs. By condition is meant the degree of fatness. Prime butcher hogs must be well covered with a thick layer of fat on the outside of the carcass, be well rounded out at the rump, thus making a socket in which the tail is set, be well filled out on neck up to the face, have a broad, fat back with much fat on sides and on belly, and be well filled in flanks and in twist. Besides this, they must be free from flabbiness, and show a firm, even, and symmetrical development. Plates 2, 4, and 7, pages 426, 429, 431.

GOOD BUTCHERS.

Hogs of this grade, though not as good as the prime butchers, are still very good representatives of the porcine family in a high state of development. Compared with prime butchers, the good butchers may be slightly deficient in form, or a little lacking in quality, or maturity, or may be lacking somewhat in condition. The deficiency may be in any one or in all of these characteristics; if in only one, it may be more marked,



PLATE 3. GOOD HEAVY BUTCHERS

and if in all, it must be only slight in each to permit the hog to still grade as a good butcher. Plates 3, 5, and 8, pages 428, 430, 431.

COMMON BUTCHERS.

These are found only in the medium and light butcher classes. Taking hogs as a whole, as they come to the yards the common butchers are still of the better grades. There is not the difference between these and prime butchers that there is between "common rough steers" and "prime steers" in the grades of beef cattle. The common butcher hog is one that shows considerable evidence of having been well fed, and possesses compactness, smoothness, and firmness. Frequently, however, he is not a mature animal, and is considerably more deficient in form, quality, and condition than the prime butcher hog. Plates 6 and 9, pages 430, 432.

In different markets and different market reports various terms are used to represent all or part of this class of hogs. Some of the names that are commonly used are "heavy shipping," "selected," "mediums and butchers," "mediums and heavies." The term "heavy shipping hogs" cannot consistently be used for this class, as the same kind of hogs are used for home consumption. By "shipping hogs" are meant hogs that are bought in a market like Chicago and shipped elsewhere to be slaughtered. This term may include hogs of several different classes and grades. "Hog shippers," as used in market reports, means men who buy hogs on the market and ship them out again to some other market. The term "mediums and heavies" is a term that means hogs of medium and heavy weight, and may have reference to hogs in two entirely different classes.



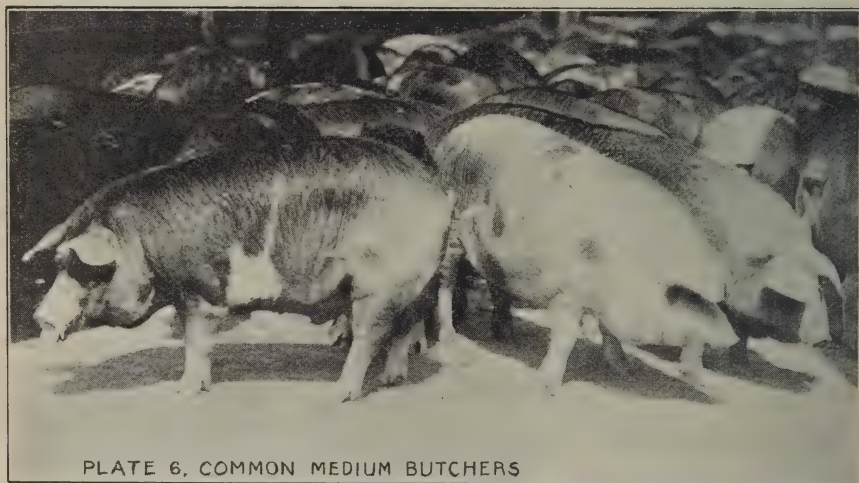




PLATE 7. PRIME LIGHT BUTCHERS

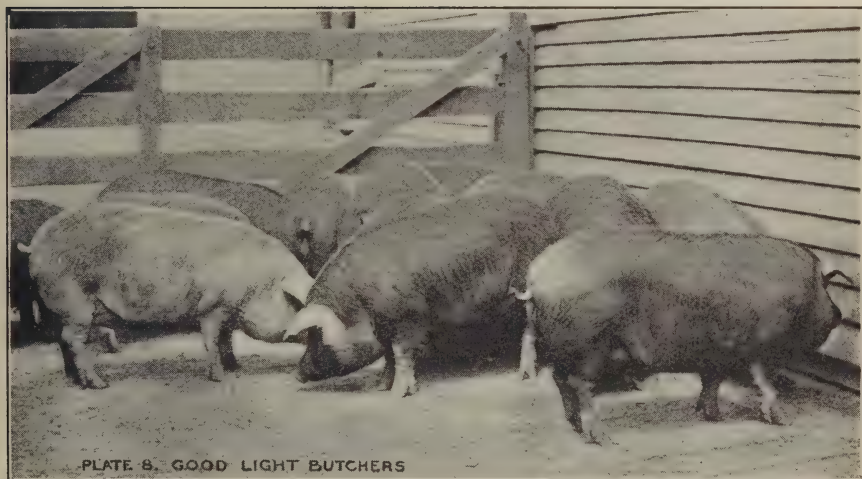


PLATE 8. GOOD LIGHT BUTCHERS



PACKING HOGS.

As a whole, the hogs of this class are of a poorer grade than are the butcher hogs, and it is here that we find old brood sows and all other hogs, except the poorer classes, such as roughs, boars, and coarse stags, that are heavy enough for this class and not good enough for the butcher hog class.

This is the class of hogs from which, as the name indicates, the packing industry has received its name. The side pork from these hogs is used principally in the various processes of curing. It is made into mess pork, short cut mess pork, dry salt sides, and the hams and shoulders are cured. About forty percent of the hogs coming to the Chicago market annually are of this class. They range in age upwards of about nine months. A 200-pound packing hog is usually an older hog than a 200-pound butcher hog. He has not been fed in the manner necessary to make a butcher hog, consequently has required more time to attain a given weight.

This class of hogs is subdivided into three subclasses, viz.:

Heavy packing, 300-500 lb.

Medium packing, 250-300 lb.

Mixed packing, 200-280 lb.

Heavy packing includes the heavy hogs of this class and medium packing the lighter hogs. Mixed packing is a subclass that is somewhat characteristic in itself. This is representative of hogs as they come to the yards from local buyers in the country, and represents hogs of different classes as well as different grades, as the name indicates. There may be heavy packing, medium packing (medium meaning medium in

weight, not in quality), some light hogs, and even a few butcher hogs in the drove. Such droves of hogs are frequently seen on the market. In fact, a great many come in this way, and are simply called mixed packing, and in some cases mixed hogs, and sold to the packer without sorting. In such cases the sorting is done after slaughtering, when the carcasses are being cut, the heavy ones being sent one way and the lighter ones another.

This kind of hogs must necessarily sell at a slight disadvantage. A mixed drove of hogs, even if they are composed of good individuals, never looks as well as a drove that are all of the same size, and of course they sell to some extent on their appearance. If a commission man will sort up such a car of hogs and sell them in their various classes, he will always have a few of one class in a lot by themselves that will not sell so well as would a larger drove—a drove sufficient to make a carload.

It is this class of hogs principally, viz., mixed packing, that furnishes a field for operation to the speculator. He buys several carloads of these mixed packing hogs and sorts them into their various classes and resells them. By so doing he gets enough of a class to make carload lots with which to fill shipping orders or with which to attract the eye of a local buyer, and thereby sell his hogs at a profit.

The speculator is a desirable adjunct to all great central markets. He helps to create competition, to tide over dull times in the market by taking some of the surplus hogs and selling them on days when hogs are more scarce. It is true that the shrewd speculator sometimes makes considerable profit in his operations, but very often the speculator, by means of his plunging business methods, pays more for a drove of hogs than is offered by other buyers. He has the advantage in that all the hogs he handles pass through his hands as his private property, and he can grade them both as to grade and as to numbers so that they will sell to the best advantage. This the commission man cannot always do, because he would not have enough of a grade to make an attractive drove. The grades of packing hogs are as follows:

Good heavy packing, plate 10, page 434.

Common heavy packing, plate 11, page 436.

Inferior heavy packing, plate 12, page 437.

Good medium packing, plate 13, page 437.

Common medium packing, plate 14, page 438.

Inferior medium packing, plate 15, page 438.

Good mixed packing, plate 16, page 439.

Common mixed packing, plate 17, page 440.

Inferior mixed packing, plate 18, page 441.



PLATE 10. GOOD HEAVY PACKING

GOOD PACKING HOGS.

The grades in this class, either heavy, medium, or mixed packing, are rather difficult to describe. Being a mixture of several different kinds of hogs, the terms good, common, and inferior may have several interpretations. There may be a lot of old sows that bear evidence of once having had pigs, but are fitted in very high condition. They are very good in form, quality, and condition, but having performed maternal duties, they are not capable of so high a finish, and consequently cannot be classified with butcher hogs. These, then, are good packing hogs, either heavy or medium, according to weight. Again, there may be a drove of barrows that are not well enough developed and are too much lacking in form, quality, and condition to go into the butcher hog class, but still bear marked evidence of being of the fat hog type and breeding and these are graded as good packing hogs. Then again, there may be a mixture of sows and barrows quite varying in quality and condition, but still bearing sufficient evidence as a whole of good breeding, form, and quality to grade as good packing hogs. Plates 10, 13, and 16; pages 434, 437, 439.

COMMON PACKING HOGS.

This grade of packers is similar to the foregoing, except that they need not show so perfect a form, so fine a quality, or show so much evidence of having been fed. They are, however, strictly of the fat or lard hog type, and show that they have been fitted for market. Plates 11, 14, and 17; pages 436, 438, 440.

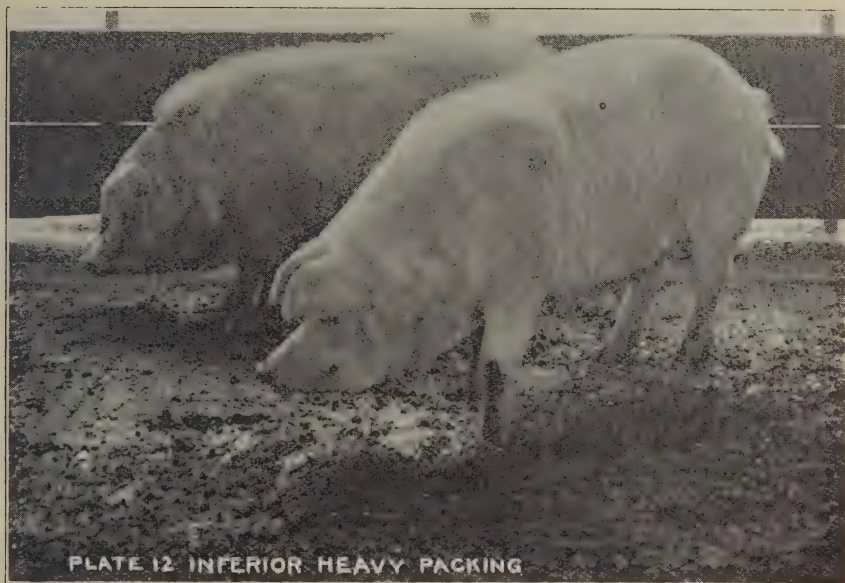
INFERIOR PACKING HOGS.

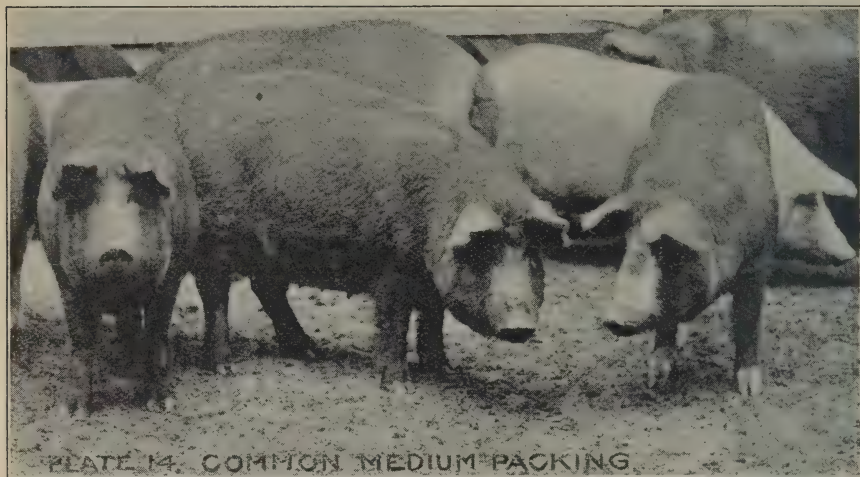
In this division of the hog market we find hogs that are poor in form, coarse in quality, and much lacking in condition. They are, however, good enough in these various characteristics to allow them to pass unquestionably as fit for the block. Plates 12, 15, and 18; pages 437, 438, 441.

In the various market reports we find such terms as "mixed packing" "heavy packing," "mixed hogs," "mediums and heavies," and "mediums and butchers," to represent a part of all of the hogs in this class. The first two terms are names of subclasses, and mean what the name indicates. "Mixed hogs," is too vague a term, as it may mean almost anything. The two latter terms may stand for hogs of different classes; "mediums" may refer either to packing or to butcher hogs; "heavies" may refer either to heavy packing or to heavy butcher hogs; and "butchers," of course, refers to butcher hogs.



PLATE II. COMMON HEAVY PACKING









—PLATE 17 COMMON MIXED PACKING



PLATE 16. INFERIOR MIXED SACKING

LIGHT HOGS.

The class of light hogs includes all hogs within the weight limits, 125-220 lb., except roughs, stags, and boars, which form separate classes. About fifteen percent of all the hogs coming to the Chicago market are of this class. They range in age from five to eight months. Since this class includes practically all hogs within the given weight limits, they must necessarily be quite different as to form, quality, and condition. Such being the case, the meat from the same is prepared differently, thus making the subclasses of more importance than in the two former classes. These, then, must be considered separately. They are as follows:

Bacon hogs, { Eng., 160-220 lb.
 { U. S., 155-195 lb.

Light mixed hogs, 150-220 lb.

Light light hogs, 125-150 lb.

BACON HOGS.

Hogs of this type are used for the production of bacon. This is pork that has been salted and then smoked. Breakfast bacon, as is well known, is cut from the side of a hog, and is prepared as above. Where this kind of pork is prepared from a carcass, the hams and shoulders are sold separately. Much of the English bacon is cut into what is called a "Wiltshire side." This is the whole side, with simply the head and feet cut off.

In order to understand this subject more fully, we must first consider in a general way what is meant by

ENGLISH BACON HOGS.

The bacon hog that is representative of this class belongs primarily to Great Britain, Denmark, and Canada. In recent years, this hog has been introduced into the United States, and is rapidly establishing for itself a market class. Many hogs are sold on the Chicago and other markets of the United States for bacon purposes, but the greater part of them are not of the ideal bacon type.

This hog must be long in body, deep in side, with comparatively narrow back, narrow and light hams and shoulders, and light, muscular neck. This form is desirable because it is the side of the hog that furnishes the best and most expensive cuts, and it is necessary to have as much as possible of this at the expense of the other parts. This hog must also show indications of having firm flesh, be well covered with lean meat or muscle, and must not have an excess of fat on the outside of the carcass. The fat on the outside should not be more than one to one and a quarter inches in thickness, and should be evenly distributed over the

entire carcass. The weight must be between 160 and 220 pounds, as this makes the most desirable cuts as to size, flavor, and firmness. From the very nature of a cut of bacon, size is of much importance. A hog smaller than the given weight would furnish a side of bacon that would be too thin, and one larger than this would furnish one that would be too thick.

A hog old enough, that with good care and breeding will weigh from 160 to 220 pounds, furnishes bacon that is of the best flavor. A hog smaller than this would very likely be too young and one heavier than this would be too old to furnish bacon of the best flavor. In firmness of flesh, also, the 160 to 220-pound bacon hog is likely to be most desirable. A hog younger than is required to produce this size would have too much water in its flesh; for the younger the animal, the more water it has incorporated in its system, and this excess of water in the system of the young hog not only detracts from the firmness of the flesh, but also replaces much of the food value, thus forming a meat that has less "substance." When a hog is heavier than 220 pounds, he is not so good for bacon purposes, because when beyond the age required to produce this weight there is a greater tendency to lay on fat, not only on the outside of the carcass, but also to intermix more fat with the lean meat, thus producing too much fat in proportion to lean meat for the best bacon. After this age there is also more of a tendency to lay on fat unevenly and in patches, and where this occurs it is impossible to produce good bacon.

These hogs are graded on the market as:

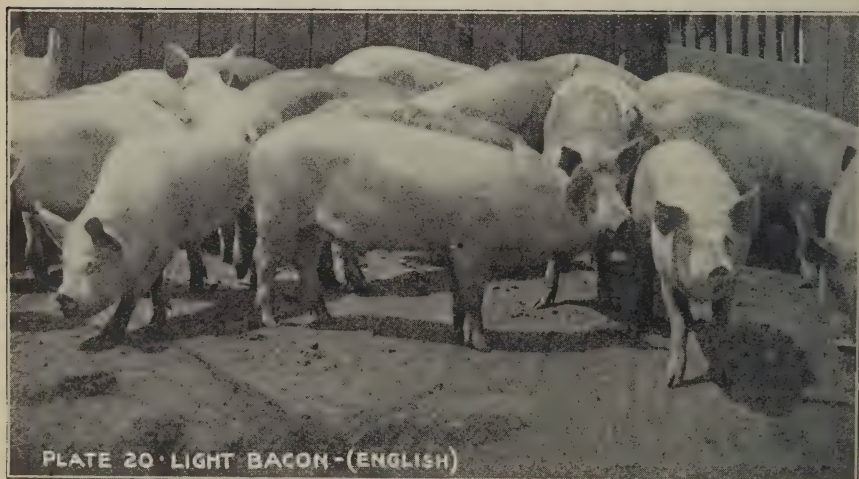
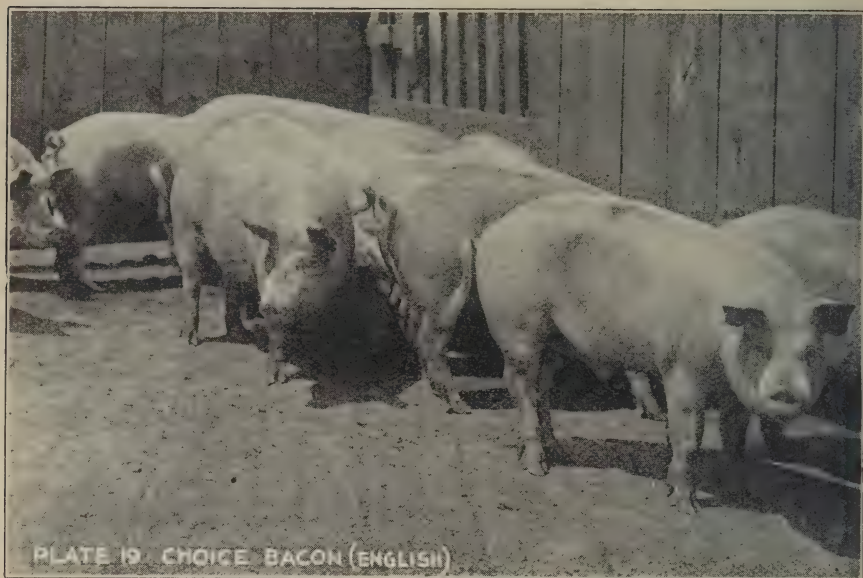
Choice bacon (Eng.), plate 19, page 444.

Light bacon (Eng.), plate 20, page 444.

Fat bacon (Eng.), plate 21, page 445.

By the term choice, in reference to a bacon hog, is meant one that conforms as nearly as possible to the above description. It must have the form that is characteristic of this type of hog, and must have the best quality and condition that is desired for the bacon trade. The indications of quality are the same as given on page 427.

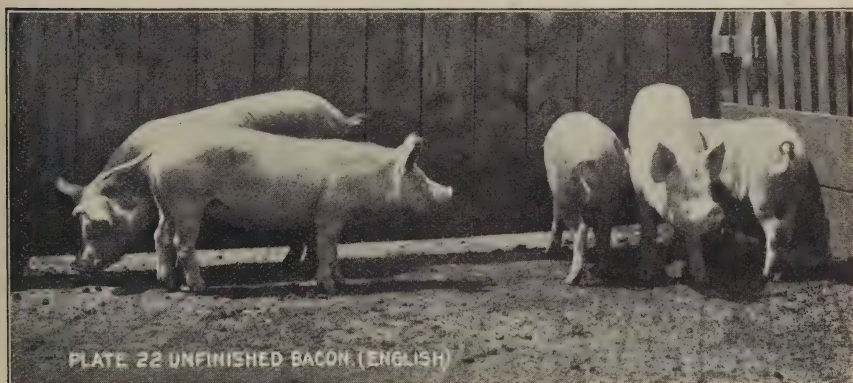
Condition.—By condition is meant the degree of fatness of an animal. The bacon hog is not a fat hog, consequently when a bacon hog is in good condition for market, he is an entirely different looking hog from a fat or lard hog when in such condition. To be in good condition a bacon hog must have a good development of lean meat or muscle, with the proper amount of fat as outlined above. He must be smooth, well developed, and have a large proportion of edible meat, while the proportion of fat and other offal must be small. Hams, shoulders, jowls, and neck must also be small in proportion to length and depth of side. If a hog has all these characteristics of form, quality, and condition developed to a marked degree, it would be considered a choice bacon hog. Plate 19, page 444.





A light bacon hog, plate 20, page 444, resembles a choice bacon hog in form, but is lighter in weight, usually poorer in condition, and may be coarser in quality. A fat bacon hog, plate 21, page 445, resembles a choice bacon hog except that he is too fat. He may or may not be too heavy. Plate 22, page 445, shows a group of unfinished bacon hogs. They have the proper form, but are lacking in weight and condition.

As said before, hogs of this class were in the past produced principally in Great Britain, Denmark, and Canada, where the conditions were more favorable for the production of this class of hogs. In these countries corn is grown in very limited quantities, and the principal feed for hogs is barley, oats, peas, rye, roots, wheat, and its products. These feeds, together with the exercise obtained in roaming over pastures, are conducive to the production of the best bacon.



It may be thought that the production of bacon is possible only with certain breeds of swine and that these breeds will always produce bacon under all circumstances. While this is true in a general way, it is not always true. It is the feed and mode of life that produces the bacon hog and that enables him to retain his form as such after he has been developed. It would require only a few years, by taking a bacon hog and confining him in a small pen, feeding him and succeeding generations on corn alone, and selecting the breeding stock with the desired end in view to produce a hog very similar to the present day fat or lard hog of the United States. It is also true that by selection, care, and proper feeding a bacon hog could in time be produced from the above mentioned fat or lard hog.

BACON HOGS OF THE UNITED STATES.

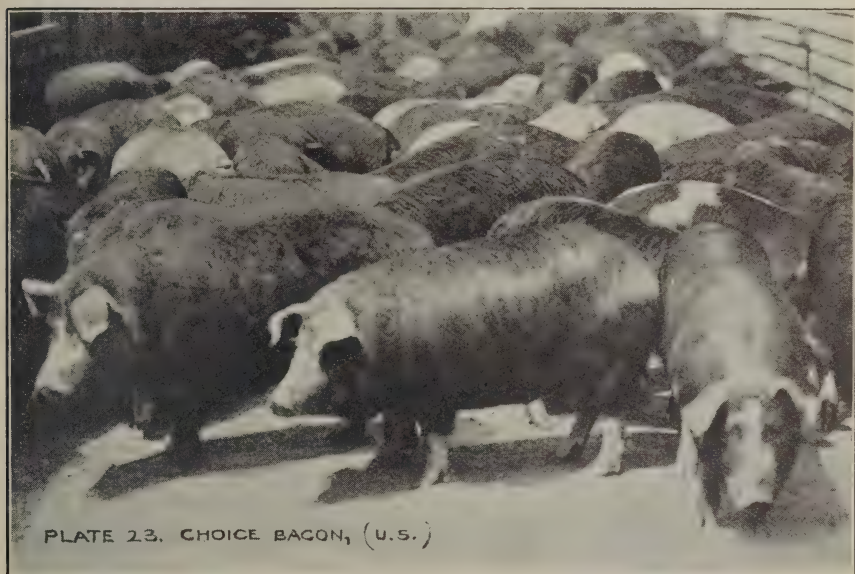
The bacon hog of this type differs considerably from the English bacon hog. There is, however, a growing tendency toward the typical bacon type. The indications point to the fact that we are at the "parting of the way," and that in the future we will have a place for the ideal bacon hog as well as for the fat or lard hog. Corn is at present being used for other purposes, such as the manufacture of corn-starch, whiskey, and oil. The latter is used for various purposes, as for lubricating, a table oil, as a substitute for olive oil, linseed oil, etc. This has caused the price of corn to go up to nearly what other grains, used as hog feeds, are worth. At the same time, a ration of all corn, which usually forms the principal part of the feed of the fat or lard hog, is coming to be generally recognized as detrimental to the best development of swine from the breeder's standpoint. These things are the cause of a gradual drifting toward a more mixed ration in swine feeding, and usually a ration containing more protein or flesh forming material. Coupled with this, there is not so great a demand for fat pork as there formerly was, and shipping and cold storage facilities are much better, consequently more fresh and lean meats are used. These various factors are gradually, but most surely effecting a change in the character of swine in the United States. The all fat hog of the past will in the future be partly replaced by the bacon hog, and the fat or lard hog as a whole will in the future more nearly approach the bacon hog in form than in the past. Of course, there will always be a demand for lard, consequently there will always be a place for the fat or lard hog. But the bacon hog will occupy a more prominent position in the future than he has in the past. There is a demand on the markets of this country from foreign countries and more largely from our own country, for bacon, and there being few bacon hogs to supply the demand, the trade is supplied from the lighter hogs of the fat or lard hog type. This bacon, however, does not command so high

a price on the market as does bacon from typical bacon hogs. The bacon hogs under consideration here weigh from 155 to 195 pounds, and range in age from six to eight months. They are simply hogs selected from the light hogs in general, that conform as nearly as possible to the bacon type. They are not very fat, have fairly good development of muscle, or lean meat, and are as long and deep inside as is possible to obtain them. About 20 percent of the light hogs that come to the Chicago market are of this type. They are handled on the market as

Choice bacon (U. S.), plate 23, page 447.

Good bacon (U. S.), plate 24, page 448.

Common bacon (U. S.), plate 25, page 448.



Choice bacon hogs are the best of this class; they are hogs that show good length and depth, good quality, and are smooth, well developed, and not very fat. They are hogs that have had considerable exercise and have not been fed on an exclusive corn ration. These bacon hogs are selected for the most part from shipments that come from outside of the corn belt, where the principal feed is similar to that used in Great Britain, Denmark, and Canada for bacon production, viz., oats, barley, rye, peas, skim milk, and pasture. These are the feeds that are conducive to the production of the best bacon when fed to hogs of the bacon type, and when fed to hogs of the fat, or lard hog type, bacon hogs such as we have under discussion here are produced. These bacon hogs have more fat on the outside and less lean meat on the inside of their carcasses than the typical bacon hogs, but are better in these



respects than the typical fat, or lard hogs. In truth, this bacon hog is an intermediary between the fat or lard hog and the typical bacon hog, being more like the former than the latter. Plate 23, page 447.

The good bacon hogs of this class may be of poorer quality, may be lower in condition, or may be too fat or too much of the fat hog type. Any one or all of these conditions would be the cause of hogs grading lower than choice. Plate 24, page 448.

If there is a still more marked deficiency in these characteristics, the hog will grade as a common bacon hog. But still this hog has sufficient quality and condition to show that he has been well bred and has been fed so that his sides will do to cure for the cheaper grades of bacon. Plate 25, page 448.

LIGHT MIXED HOGS.

About 55 percent of the light hogs coming to the Chicago market are of this class, and here we find somewhat of a miscellaneous class quite similar, except as to weight, to mixed packing hogs. This class contains the hogs of the light butcher weights that are too poor in quality, form, and condition for butcher hogs. It also contains hogs of the same weights as the bacon hogs, but that are too much of the fat or lard type hog for bacon. This class, then, is the "dumping ground" for the outcasts of two former classes of hogs; in one case it takes the poorer hogs and in the other case the better hogs, considered from the fat or lard hog standpoint. Hence the appropriateness of the name. Hogs of this class are used principally for the fresh meat trade and weigh from 150 to 220 pounds. They range in age, from five to seven months, and grade as

Good light mixed, plate 26, page 449.

Common light mixed, plate 27, page 450.

Inferior light mixed, plate 28, page 450.

Being familiar with the kind of hogs in this class, we are better able to judge as to their grades. They are good, common, and inferior, in proportion as they are good, common, and inferior in form, quality, and condition, or in proportion as the better hogs in the class are in excess of the poorer ones. Plates 26, 27, 28, pages 449, 450, 450.





LIGHT LIGHT HOGS.

About 25 percent of the light hogs coming to the Chicago market are of this class. This is a class of hogs ranging in weight from 125 to 150 pounds, and in age from five to six months. They bear the name of "light light," because they are the lightest of light hogs. While the "light butchers" and "bacon hogs" are the selected kinds of their respective weight, with consequent small variation between the different

grades, the class of "light light hogs" includes all the hogs of this weight; consequently the range in the grades is wider. They are used principally for the fresh-meat trade, and the grades are as follows:

Good light lights, plate 29, page 451.

Common light lights, plate 30, page 451.

Inferior light lights, plate 31, page 452.

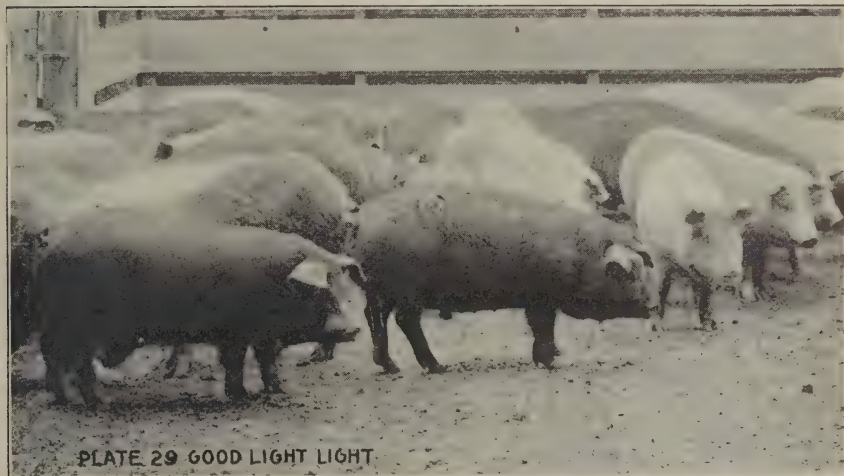


PLATE 29 GOOD LIGHT LIGHT

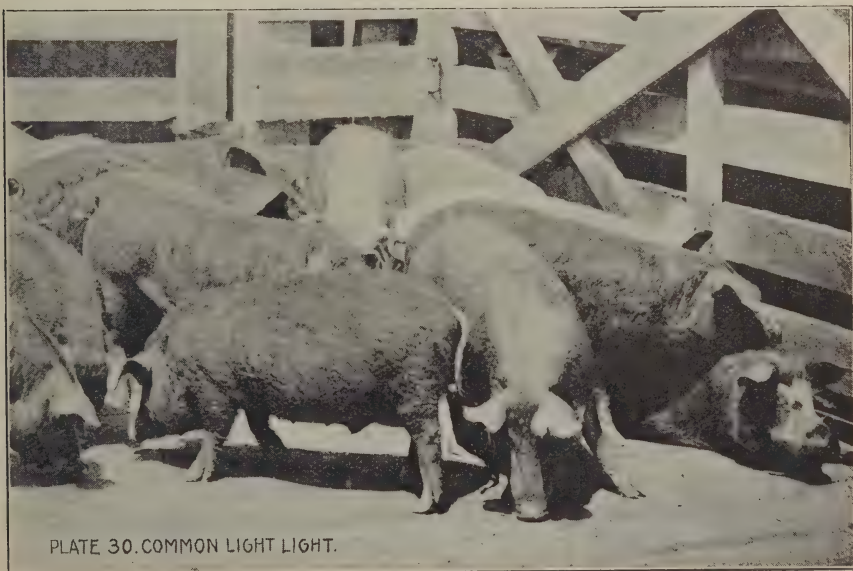


PLATE 30. COMMON LIGHT LIGHT.

Good light lights are the best hogs of this type that come to market, while the common light lights are of a poorer grade, and the inferior light lights are the poorest grade within these limits. These latter are, however, by no means the poorest grade of hogs that come to market. Plates 29, 30, and 31; pages 451, 451, 452.



In the Buffalo market light hogs weighing from 130 to 180 pounds are called "Yorkers"; the lighter ones are called "light Yorkers," and the heavier ones "best Yorkers." This is only a colloquial expression, and by it are meant hogs such as are represented by "bacon hogs," "light lights," and "light mixed" hogs. They are called Yorkers because hogs of this class find ready sale on the New York market and are very often shipped there from Buffalo. Being shipped from Buffalo, they might under another nomenclature be called "shippers."

"Dairies" is another colloquial term used in Buffalo, and means hogs that have been fed on slops or refuse from dairies. The flesh of these hogs is not so firm nor will they dress so well as will corn-fed hogs.

PIGS.

Pigs, as they are considered on the market, range in weight from 60 to 125 pounds, and in age from three and one-half to six months. This class, the same as that of light light hogs, takes in all the pigs that range within the given weights. These are used principally to supply the demand from the cheaper restaurants and lunch counters, and are

in greatest demand in winter, being hard to preserve fresh in summer and too young to cure. About 10 percent of the hogs coming to the Chicago market are of this class. They are graded as follows:

Choice pigs, plate 32, page 453.

Good pigs, plate 33, page 453.

Common pigs, plate 34, page 454.

They are choice, good, and common pigs, in proportion to their approach to the ideal of a fat hog. Here, as in the other classes, form, quality, and condition determine their grade. They are choice when these characteristics are well developed, and good and common as these qualities are less marked. Plates 32, 33, and 34; pages 453, 453, 454.





ROUGHES.

In this class we find hogs of all sizes that are coarse, rough, and lacking in condition. If they are too inferior to be classed as packing hogs or as light mixed hogs, they go into the class of roughs. The pork from these hogs is used for the cheaper class of trade for both packing and fresh meat purposes. In market reports pigs and roughs are frequently classed together, not because they belong in the same class, but because they sell at approximately the same price. Plate 35, page 455,

STAGS.

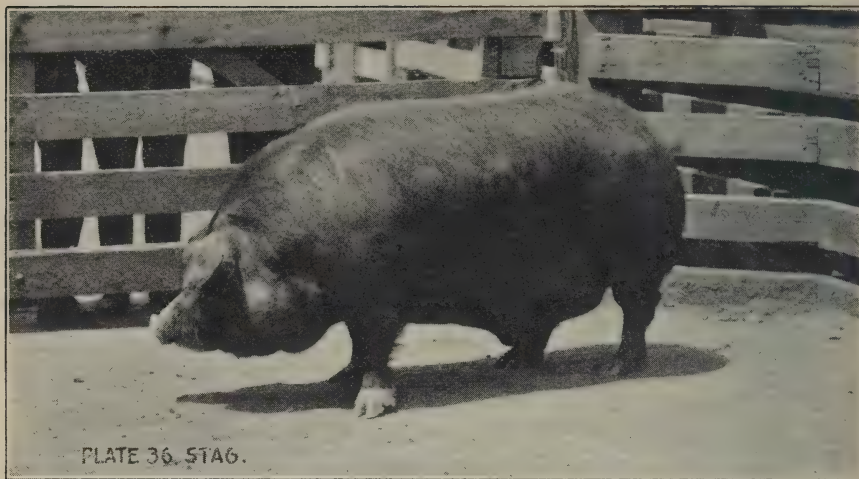
Stags are hogs that at one time were boars beyond the pig stage and have been subsequently castrated. They sell with a dockage of 80 pounds. If they are of good quality and condition and do not show too much stagginess, they go in with the various grades of packing hogs. When they are coarse and staggy in appearance, they are sold in the same class with boars. The intermediary grades sell for prices ranging between these extremes, dependent upon their freedom from stagginess and their quality and condition. Plate 36, page 456.

BOARS.

Boars are always sold in a class by themselves and bring from two to three dollars per hundredweight less than the best hogs on the market at the same time. They always sell straight, with no dockage. There are no distinctions as to grades; they simply sell as boars. Of course, if there are marked differences as to quality and condition, the price varies a little accordingly. The pork from these animals is used to supply the cheaper class of trade, and also for making sausage. Plate 37, page 456.



PLATE 35. ROUGHS



MISCELLANEOUS.

ROASTING PIGS.

This is a class of pigs from three to six weeks old and weighing from 15 to 30 pounds. These are not generally found quoted in market reports, as they come to market in such small numbers and only during holiday seasons. Pigs of this class usually are of very nearly uniform grade. They are taken direct from their dams, dressed with head and feet on, and served like spring chickens or turkeys. The price varies greatly, ranging all the way from regular live hog prices to that paid for poultry. Plate 38, page 457.



FEEDERS.

Feeders are hogs that are bought on the market and taken back to the country to be further fed. This is practiced only to a very small extent. First, because the price per hundredweight of the animal is not usually much enhanced by such an operation, as is the case with cattle. Many times such a hog would sell for less money per pound after being fed to a heavy weight, than the price paid for him when bought as a pig. This is due to the fluctuation in price between heavy and light hogs. Second, there is too much danger of the hogs contracting diseases, such as hog cholera and swine plague, by going through the yards and by being shipped in cars that may be infected. Furthermore, the life of a hog being short and the feed required to put him in market condition not being very great, he is usually fitted for market in first hands. Then again, a pig that has been fed on corn would not be a profitable feeder, owing to the tendency to lay on fat at the expense of the muscle and framework of the body.

GOVERNMENTS.

Before hogs are allowed to pass over the scales to be weighed out to the packer, the speculator, the shipper, or to any one else who may choose to buy them, they must first pass the scrutiny of a government inspector. All hogs that are not considered sound in every respect are tagged by this inspector and retained for further inspection. These are called Governments. Plate 39, page 458. They are usually bought up by a local dealer and taken to one of the smaller packing houses, where they are slaughtered under the supervision of an inspector. If found to be affected so as to make their flesh unfit for human food, they are condemned, slaughtered, and tanked. The tank is a large steam-tight receptacle like a steam boiler, in which the lard is rendered under steam pressure. This high degree of heat destroys all disease germs with which the diseased carcass may have been affected. The product of the tank is converted into grease and fertilizer. This many people consider poisonous because it is made from dead and diseased animals. Such, however, is not the case. Most diseases are caused by bacteria. These render the meat from such animals unfit for human food, on account of the danger of transmitting the disease, but they are completely destroyed in the process of rendering the lard, which is then used for the manufacture of axlegrease, soap, etc. The lean meat and bones of such animals, after going through the tank, are used for the manufacture of fertilizer. This also has all disease germs with which it has been affected completely destroyed and is perfectly harmless to be used on soil, meadow, or pasture grass. It could even be used for the manufacture of tankage and allied farm animal food products with entire impunity. The packers, however, report that such foods are not manufactured from diseased animals, but from the scraps of meat from healthy animals.



PLATE 39. GOVERNMENTS.

As has been shown, the name "Governments" is given to a class of hogs, irrespective of form, quality, and condition, that have been tagged by a government inspector at the scales. These inspectors are stationed only at large packing centers. They are hired by the Government, are thoroughly competent men, and do this work without fear or hesitation. The inspectors stationed at the smaller packing houses, where inspectors are furnished at all, are furnished either privately or by the city. Having less work to do, they cannot be paid such large salaries; consequently, men with poorer qualifications must be accepted, and there is more danger of diseased meat getting to the consumer through this channel than through the large packing houses where government inspectors are furnished. The Government, up to the present time, has been unable to get enough of sufficiently well qualified men to supply all packing houses with inspectors.

Besides the inspector at the scales, there are in the large packing houses three more government inspectors. One is stationed where he can feel of the submaxillary and cervical glands as the carcasses of hogs pass by him on the rail with the heads partially severed, exposing the glands. These glands furnish the best means of detecting tuberculosis, and the carcass of any animal that has the appearance of this disease in these glands is tagged and passed on intact, with only the intestines taken out.-

The second inspector is stationed farther down the line at a point where he can view the carcass after it has been cut open. Any carcass affected with tuberculosis, hog cholera, swine plague, or any other disease that may have been accidentally passed by the first inspector, or any that is healthy in the above-named glands and diseased in other parts of the body, is tagged by this second inspector. These two men must necessarily work very rapidly, as the carcasses of hogs pass and must be examined by them at the rate of 800 to 1,000 an hour.

The third inspector is stationed in the cooling rooms and examines critically all carcasses that have been tagged by the two former inspectors. As he examines only the tagged carcasses, he has time to give them a thorough examination. All carcasses that he finds so badly diseased as to render them unfit for human food are condemned and tanked. The carcasses in which the disease is found to be only localized and in such a manner as not to render the meat of the same unfit for use are passed. These then pass into the ordinary channels of consumption. Many times only parts of the carcass are condemned, while the rest is passed as fit for food.

In most every town throughout the country where there is a meat market there is also a slaughter-house where hogs are killed for home consumption. In these there are no inspectors, and the dealers them-

selves are not able to diagnose the various diseases, and even if they were, the loss would be so great that they would be tempted to be blind to anything that would detract from the profits of their business.

There are even small packing-houses in the smaller cities that do more than a local business; slaughtering hogs and shipping the prepared meats. Many of these have no inspectors, and all there is to prevent all animals, both diseased and healthy, finding their way into the retail channels, is the intelligence, diligence and honesty of these small packers, which it is not always safe implicitly to trust.

In view of these facts, and considering that all hogs are subject to such diseases as hog cholera, swine plague, trichinæ, and tuberculosis, the latter two being especially dangerous to man, it is evident that our most wholesome meats are most likely to come from the large packing-houses, where are stationed the government inspectors.

PEN HOLDERS.

The hogs of this class have no influence on the market; they serve their purpose, as their name indicates.

The stockyards in Chicago, for instance, are owned by the Union Stockyards and Transit Co. This firm gets its revenue from the charges for yardage of stock, for weighing the stock, for feed consumed by the stock, and for terminal switching. The commission men who sell the stock as it comes to the yards, and the speculators who handle part of it, pay nothing for their privilege of doing business in the yards. They hold their respective positions by common consent, and their respective pens by keeping hogs in them. These are called pen holders. They usually are hogs that are worth the least money, being long legged, of poor form, coarse in quality, and much lacking in condition. They are kept simply for this one purpose, viz., holding pens. Plate 40, page 461.

DEAD HOGS.

These are the hogs that have been killed in the cars in transit. They are used for the manufacture of grease, soap, and fertilizer. If they weigh 100 pounds or over, they sell for 75 cents per hundredweight. If they weigh less, they furnish no revenue to the producer or shipper, the cost of handling the same being held equal to their value. Plate 41, page 462.

To summarize the percentage number of hogs of the principal classes on the Chicago market annually we have the following, which is only an approximate estimate, and is subject to considerable variation from year to year:



PLATE 40. PEN HOLDERS



Butcher hogs, 25 percent of all hogs on the market.

Packing hogs, 40 percent of all hogs on the market.

Light hogs, 15 percent of all hogs on the market	{	Bacon, 20 percent.
		Light mixed, 55 percent.
		Light light, 25 percent.

Pigs, 10 percent of all hogs on the market.

Other classes, 10 percent of all hogs on the market.

CONCLUSIONS.

1. A thorough understanding of the market classification of hogs is very essential to all concerned in the handling of swine.

2. About two-fifths of the world's hog supply is produced in the United States and about six-sevenths of these are produced in the Mississippi Valley; hence this section of country has developed the fat or lard hog and has set the standard for hogs in other parts of the United States.

3. The fat or lard hog is such because corn has been his principal feed and because there has been a demand for pork from such a hog,

and he will conform to the present prevailing type just as long as corn remains his principal feed.

4. Classes and sub-classes are divisions into which swine are separated on account of their differences in type, weight, quality, and condition, and the grades distinguish the superior from the inferior animals within the classes and sub-classes.

5. The terms, "mediums and butchers," "pigs and roughs," "selected," "shipping," "mediums and heavies," "mixed," "Yorkers," and "dairies," are either compound or colloquial terms, and their use should be discouraged.

6. Butcher hogs are the best hogs from the fat or lard hog standpoint that come to market, and should be used as a standard for comparison.

7. From the bacon market standpoint the English bacon hog is the ideal toward which hogs are being developed.

8. To the close observer it is apparent that the gradually changing conditions brought about by the development of the United States, and the increase in the price of corn, resulting from its varied commercial uses, cause the hog to be fed a more mixed and usually a more nitrogenous ration. This will in the future affect the type of the hog of the United States, so that it will more nearly approach that of the English bacon hog.

"'Twere easier to teach twenty men what were good to do than to persuade one man to do."—*Modern Shakespere*.

CIRCULAR NO. 68

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

URBANA, ILL., APRIL, 1903.

METHODS OF MAINTAINING THE PRODUCTIVE CAPACITY OF ILLINOIS SOILS.*

BY CYRIL G. HOPKINS, PH.D., CHIEF IN AGRONOMY AND CHEMISTRY.

If the greatest study of mankind is Man, the next greatest study is the soil ; for, upon the soil depends the preservation of Man.

If it is true that American agriculture is the fundamental support of the American Nation, it is equally true that soil fertility is the absolute support of American Agriculture.

If he who makes two blades of grass grow where but one grew before is a public benefactor, then he who reduces the fertility of the soil so that but one ear of corn grows where two have been grown before is a public curse.

*An address read before the Illinois State Farmers' Institute at Bloomington, February 25, 1903, now published as an Experiment Station Circular for general distribution among the farmers of Illinois, because it is believed that this information will be of value to very many Illinois farmers and land owners. More complete data regarding the exact composition and location of all soils which have been sampled and analyzed will be published in bulletin form for free distribution within a few months. The bulletin will contain a general survey soil map of the State printed in colors, which will be much more distinct, than the map printed in this circular.

The fertility of Illinois soils ought not and need not be reduced ; Illinois land ought never to be reduced below its original productive capacity.

The only system of maintaining soil fertility which I can advocate and which can ever safely be adopted as a permanent system must be a system which can be applied to all of the soils of this State,—not to a few farms only, or for a few years only, but to all the soils of Illinois, and for all time,—yes, even more than that,—it should be a system which can be applied to the soils of adjoining states,—to Indiana and Ohio,—to Wisconsin and Iowa,—in short, to the soils of America.

How shall the fertility of the soil be maintained ? We hear two very common answers to this question :

The grain farmer says we must grow clover.

The live stock farmer says we must put the manure back on the land.

But neither of these answers really answers the question.

Clover will not maintain the fertility of the soil, and, if all of the crops which are grown on the farm are fed on the farm and the manure all returned to the land, it will not maintain the fertility of the soil, not even if clover is also grown. The only way by which the live stock farmer can maintain the fertility of his soil by the use of manure is to feed not only his own crops but his neighbors' crops also, and then put all the manure upon his own land.

This answers the question for a few farmers who are also extensive cattle feeders, but it does not answer the question for Illinois ; it does not answer the question for America ;—we cannot all feed our own crops and our neighbors' crops also.

How then shall we maintain the fertility of Illinois soil ?

There is but one answer to this question, and this answer would have saved the fertility of all the soils which have been ruined in past ages. It would have saved the soils of Palestine, a land which once flowed with milk and honey but is now a barren waste. It would have saved the soils of Greece, and of Italy, of Northern Europe and of Eastern United States, and it is the only answer which will save the soils of Illinois,—and this is the answer:

Preserve good physical conditions and then put back upon the land all of the fertility which is taken off,—not some of it, not most of it, but all of it: and not only that which is removed by cropping but also that removed by the blowing, washing, or leaching of the soil.

The whole subject of plant food is a simple one. About 95 per cent. of most agricultural plants consist of the three elements carbon, hydrogen, and oxygen, which are obtained from air and water.

Only seven essential elements are furnished by the soil, and four of these, calcium, magnesium, iron and sulphur, are used by plants in such small amounts and are contained in all ordinary soils, in such large amounts that they are practically never exhausted from the soil.

The productive capacity of practically all soils in good physical condition is measured by the available supply of the three elements, nitrogen, phosphorus, and potassium. These are the elements which are present in nearly all soils in comparatively small amounts and yet are absolutely required by all agricultural plants, and in very considerable quantities.

How shall the fertility of the soil be maintained? By maintaining the supply of nitrogen, phosphorus, and potassium, and preserving good physical conditions. How shall the productive capacity of a soil be increased? By increasing the supply of that element which is most deficient in the soil.

The live stock farmer understands the value of a balanced ration in stock feeding. Let us also bear in mind that plants are living things, and that balanced rations are of even greater importance to them than to animals. Timothy hay and corn-and-cob meal have some place in animal feeding, but they do not make the best possible balanced ration for young cattle or milk cows, nor could you make a balanced ration by adding to them excelsior straw and sawdust meal. Likewise a plant which is starving for phosphorus is not benefited by plowing under a crop of green rye or even by feeding it more nitrogen or potassium; indeed such treatment would tend to still further unbalance the soil and might even produce an injurious effect upon the plant, as appears to have been the case to a slight extent in some experiments (see Table 7, (a) 8 and (b) 7).

Special Note. The tables given in this circular have been prepared with very great care. They may not be very entertaining to the careless reader; but to any one who is willing to take some time to study them, to compare one with another,—in short to do some real thinking along these lines,—to such a one these tables contain a large amount of very useful and valuable information bearing directly upon the business of farming and the science of agriculture.

By referring to Table 1, which is self explanatory, one may see some of the absolute requirements of different kinds of farm produce for the different elements of plant food.

TABLE I. FERTILITY IN FARM PRODUCE.
(Approximate maximum yields per acre.)

Produce.		Pounds.			Value.			
Kind.	Amount.	Nitro- gen.	Phos- phorus.	Potas- sium.	Nitro- gen.	Phos- phorus.	Potas- sium.	Total Value.
Corn, grain...	100 bu.	100	17	19	\$15.00	\$ 2.04	\$ 1.14	\$18.18
Corn stover...	3 T.	48	6	52	7.20	.72	3.12	11.04
Corn crop ...		148	23	71	22.20	2.76	4.26	29.22
Oats, grain ..	75 bu.	45	7	9	6.75	.84	.54	8.13
Oat straw....	2 T.	24	4	40	3.60	.48	2.40	6.48
Oat crop.		69	11	49	10.35	1.32	2.94	14.61
Wheat, grain.	40 bu.	46	6	11	6.90	.72	.66	8.28
Wheat straw.	2 T.	19	4	34	2.85	.48	2.04	5.37
Wheat crop..		65	10	45	9.75	1.20	2.70	13.65
Timothy	2 T.	48	6	47	7.20	.72	2.82	10.74
Clover	3 T.	120	15	90	18.00	1.80	5.40	25.20
Cowpea hay.	3 T.	140	14	95	21.00	1.68	5.70	28.38
Alfalfa	8 T.	400	36	192	60.00	4.32	11.52	75.84
Apples.....	600 bu.	47	2	57	7.05	.24	3.42	10.71
Leaves	4 T.	59	7	47	8.85	.84	2.82	12.51
Wood growth	$\frac{1}{80}$ tree	6	2	5	.90	.24	.30	1.44
Total crop...		112	11	109	16.80	1.32	6.54	24.66
Potatoes	300 bu.	63	13	90	9.45	1.56	5.40	16.41
Sugar beets..	20 T.	102	18	157	15.00	2.16	9.42	26.58
Fat cattle ...	1,000 lb.	25	7	1	3.75	.84	.06	4.65
Fat hogs	1,000 lb.	18	3	1	2.70	.36	.06	3.12
Milk	10,000 lb.	57	7	12	8.55	.84	.72	10.11
Butter.....	500 lb.	1	0.2	0.1	.15	.02	.01	.18

The table is arranged to show the number of pounds of each element required by different kinds of produce on the basis of approximate maximum yields per acre. Of course, proportionate amounts would be required for any other yields which one may wish to consider, but I think we should be most interested in knowing the amount of plant food required to make maximum yields.

The total value of the elements is computed on the basis of the present market values,—

Nitrogen, 15 cents a pound.

Phosphorus, 12 cents a pound.

Potassium, 6 cents a pound.

It should be borne in mind that the principal value given is for the element nitrogen, which, however, the farmer does not need to purchase. The total quantity of phosphorus or potassium required by crops could be supplied at very moderate cost.

I offer the following simple rules for improving soils and feeding plants:

Rule 1—If the soil is acid, or sour, apply lime to it to make it sweet.

Rule 2—If the soil is poor in nitrogen only, grow clover or some other legume which has the power to secure nitrogen from the air.

Rule 3—If the soil is poor in phosphorus only, apply bone meal or some other form of phosphorus.

Rule 4—If the soil is poor in potassium only, apply potassium chlorid or some other form of potassium.

Rule 5—Always save and use all the barnyard manure you have, and also all you can economically obtain from others, and make liberal use of green manures when necessary to maintain the supply of organic matter in the soil.

In connection with these five rules for improving soils and feeding plants, I offer the following suggestions :

1. REGARDING LIME.

Lime is the only material which we can use for correcting the acidity of soils. It may be used in several forms: (1) fresh burned quicklime, which is calcium oxid, a compound of the elements calcium and oxygen; (2) fresh slacked lime, which is calcium hydroxid, a compound of quicklime and water; (3) old air-slacked lime, which is calcium carbonate, a compound of quicklime and the carbon dioxid from the air; (4) fine ground limestone, which also is calcium carbonate, exactly the same as old air slacked lime; (5) marl, which also contains calcium carbonate, the same as limestone.

Any of these five different forms of lime may be used to correct the sourness, or acidity, of soils, and after the acidity of a soil is once corrected, probably half a ton of lime per acre once in five years will be enough to keep the soil sweet. From the knowledge which we have thus far obtained, we believe that old air-slacked

lime, fine ground limestone, and marl are the most economical forms of lime to use.

Fresh burned lime (quicklime) can be delivered in bulk at almost any point in Illinois for \$5.00 a ton in carload lots.

Slacked lime can be bought from J. B. Speed & Company, Louisville, Kentucky, in 100-pound bags, on board cars at their works at Milltown, Indiana, for \$2.50 a ton, if the empty bags are returned in good condition. The freight rate is \$1.00 to \$1.20 per ton in carload lots to such points as Centralia, Olney, Salem, and Odin.

Old air-slacked refuse lime can frequently be found in large quantities lying about the lime kilns in different parts of the State. It often contains some cinders and some lumps of stone which could be easily screened out. I believe lime companies could screen this material and place it on the cars for about 50 cents a ton, provided they could sell large quantities of it.

Fine ground limestone is now offered for sale by the Crystal Carbonate Lime Company, of Elsberry, Missouri, for \$1 per ton in bulk loaded on the cars at Elsberry. The special freight rate on this material to some points in Central Illinois (Springfield and Peoria) is \$0.80 to \$1.00 a ton, in car load lots. The Mitchell Lime Company, Mitchell, Indiana, have quoted fine ground limestone delivered at Odin, Centralia, Mt. Vernon, etc., for \$2.70 per ton in bulk in car load lots. A plant for grinding limestone to a fine powder can be erected at a cost of less than \$8,000; and, with the abundance of excellent limestone in different parts of Illinois, there is no reason why we should not have fine ground limestone delivered at any point in Illinois at very moderate cost.

Although our absolute knowledge upon the subject is still meager, my opinion is that fresh burned lime or fresh slacked lime will not prove to be the best form of limes to use, partly because they evidently have a tendency to attack and destroy the organic matter of the soil or "burn the land", as some say, and partly because the natural products (as ground limestone) are less disagreeable to handle. In power to neutralize acids, 56 pounds of quicklime would be equivalent to 74 pounds of fresh slacked lime and to 100 pounds of ground limestone, provided that all materials were perfectly dry and pure, and further provided that the full force were exerted in neutralizing soil acids, which is certainly the case with ground limestone, while with fresh burned lime (quicklime) and fresh slacked lime the force or power is evidently partly used up in destroying organic matter, although the destruction of organic matter cannot be very large. As stated before, any of these

forms of lime may well be used, but with quicklime at \$5.00 a ton, fresh slacked lime at \$3.70 a ton, and lime carbonate (ground limestone) at \$2.80 at ton, I would prefer to use the ground limestone.

As a rule, raw products are cheaper than manufactured goods, and let us bear in mind that the lime naturally in the soil is in the form of ground limestone; and I may add that the phosphates and potash salts naturally in the soil are also in the form of pulverized or finely divided rock, more or less decomposed by natural agencies.

2. REGARDING NITROGEN.

If any question pertaining to the science and practice of agriculture is settled, it is this,—that the atmosphere is the most economical source of nitrogen for all general farming; but let me ask you to bear in mind: (1) that neither clover nor alfalfa nor cow peas nor soy beans nor any other leguminous crop is able of itself to secure nitrogen from the air, but that each different legume must be provided with the particular species of bacteria which has the power to live upon its roots and to gather atmospheric nitrogen for its use: (2) that these nitrogen-gathering bacteria will not live in strongly acid soils and will not properly develop in any soil which needs lime: (3) that leguminous crops do not live upon nitrogen alone, but that they must have both phosphorus and potassium, although deep rooting legumes, like alfalfa, when once well started are usually able to obtain large supplies of those elements from the lower subsoil.

3. REGARDING PHOSPHORUS.

So far as I have discovered, in all other things Illinois farmers are intelligent, reasonable, progressive, consistent, and unprejudiced; but, regarding the use and value of that element of fertility which limits the productive capacity of a large proportion of Illinois soils, I am compelled to say that Illinois farmers, as a rule, are inconsistent, if not actually prejudiced.

Phosphorus is the one element of fertility above all others which has a high absolute and permanent value to Illinois farmers.

Nitrogen is free as air and potassium is abundant in nearly all of the soils of the State and both nitrogen and potassium remain in the straw and corn stalks and in the farm manures to a considerable extent. Phosphorus, on the contrary, is present in nearly all soils in limited amounts and it is being continually removed from the land both by grain farming and live stock farming, although two or three times faster by grain farming than by the live stock system of farming. The sin of the live stock farmer is the same as that of the grain farmer; the only difference is in degree. As

a rule, the sins of the grain farmer will fall upon his own head, while the sins of the live stock farmer will fall more heavily upon his children.

The phosphorus which is taken from the soil by plants is largely stored in the seed or grain and thus the grain farmer sells it from the farm. If the grain is fed to animals, from one-third to one-half of the phosphorus is stored in the animals' bones and thus the live stock farmer sells it from the farm.

I have talked with many Illinois farmers about using bone meal on their soil and not infrequently some one looks at me as though I were a traitor to the cause of better agriculture in Illinois and he says, "Then you advocate the use of commercial fertilizers."

Is it not a shame to call bone meal a commercial fertilizer? Pure bone meal is not a commercial fertilizer in the ordinary sense; it is not a manufactured article; it is a farm product, and any method of reasoning which justifies the use of farm yard manures will justify the use of bone meal upon the land from which it came.

In this connection let me say that I do not advocate the use of highly manufactured commercial fertilizers upon Illinois soils, not even the indiscriminate use of mixed fertilizers; and from what information we now have I strongly advise against the use of any acidulated fertilizers, such as "dissolved" bone, acidulated bone meal, acid phosphates, superphosphates, or any other fertilizers which have been treated with sulphuric acid, or oil of vitrol. Of course, I am aware that these acidulated phosphates are readily available and may give quick returns and some profit, but I am also convinced that they are too expensive and that, as a rule, their continued use works no permanent good to the land. The opinion held by many eastern farmers that they ultimately injure or "burn" the land is evidently not without some foundation; and I fear that the acid soils of Illinois would not be permanently benefited by the use of acid phosphates. On the other hand, when acid phosphates are used with lime or applied to soils which naturally contain an excess of lime, the soluble phosphate reacts with the lime and quickly reverts to a form which is no more readily available than some non-acidulated phosphates.

I believe there are only three forms of phosphorus which should be considered for use on Illinois soils:

1. Fine ground bone meal.
2. Fine ground rock phosphate.
3. Fine ground slag phosphate.

I prefer steamed bone meal to raw bone meal, partly because the steamed bone meal acts more quickly in the soil, and partly because, for its phosphorus content, the steamed bone is cheaper. The nitrogen contained in the raw bones is charged for at about 15 cents a pound, but by steaming the bones the nitrogen is largely removed in the form of glue, and the steamed bone is then sold almost wholly for its phosphorus content. Even steamed bone meal still contains some nitrogen, which is of course no objection to its use although it adds but very little to its real value for the ordinary farmer, as he can obtain nitrogen from the atmosphere at very small cost, by proper use of leguminous crops, if his soil is in suitable condition. Bone meal should be bought only on the basis of its phosphorus content.

The best steamed bone meal contains about 12 to per 13 cent. of phosphorus, which at 12 cents a pound would give it a value of \$30 per ton. It can usually be bought from fertilizer dealers in Chicago (as Nelson Morris & Company, Armour Fertilizer Works, or Swift & Company) for about \$28 a ton, in 200-pound bags, delivered at points in Illinois. Somewhat poorer grades are sold at lower prices. (Phosphorus is commonly sold under the name of phosphoric acid, by which is meant a compound of phosphorus and oxygen containing $43\frac{2}{3}$ per cent. of the element phosphorus. Consequently, if phosphorus is worth 12 cents a pound, this compound, "phosphoric acid" is worth about 5 cents a pound.)

Fine ground rock phosphate, containing 12 to 13 per cent. of phosphorus, can be bought from Robin Jones of Nashville, Tennessee, (and probably from other dealers) for \$4 a ton in bulk (or \$4.40 in bags), on board the cars at the mines, and the freight rate now in effect from the mines in Tennessee to Chicago is \$3 22 per ton of 2000 pounds. Thus, this material can be delivered in Illinois for \$7 or \$8 a ton. As it is just as rich in phosphorus as good steamed bone meal, the phosphorus in the rock would cost only 3 cents a pound. In other words, the 17 pounds of phosphorus contained in 100 bushels of corn would cost \$2.04 if bought in the form of bone meal, while it would cost only 51 cents if bought in rock phosphate. In bone meal the phosphorus for a bushel of corn costs 2 cents; in rock phosphate it costs $\frac{1}{2}$ cent. In either case the cost is small as compared with the total cost of the corn crop. If we buy the land and plow the ground, prepare the seed bed, plant the seed, cultivate the corn, and harvest the crop, why not give some consideration to feeding the plant, especially when the cost of all the farm operations in growing the corn crop is just the same whether we grow 37 bushels, or a hundred bushels, to the acre.

It seems very probable that the phosphorus in the rock phosphate will be less readily available than in the bone meal, but, if four or five times as much rock phosphate is used, its effect will probably be observed just as soon and it will certainly be much more lasting than the effect of the bone meal.

Slag phosphate is simply the finely ground slag produced in the manufacture of steel from iron made from ores which are rich in phosphorus. The best slag contains about 8 per cent. of phosphorus and it also contains some excess of lime which is added to the converter in which the iron is converted into steel. The amount of lime which the slag phosphate contains would probably add somewhat to its value for use on Illinois soils, many of which are already in need of lime; but at the present time no slag phosphate is produced in this part of the country, the iron ores used by the Illinois Steel Works being very poor in phosphorus. Considerable quantities of slag phosphate are produced in Pennsylvania, and are being used on the soils of the Eastern States. Slag phosphate can be obtained from Jacob Reese, Pottstown, Pennsylvania.

The phosphorus fertilizers which are commonly used in the United States are the most expensive kinds obtainable. They are highly manufactured articles. This is largely due to the fact that most farmers who use fertilizers demand a kind which can be applied when the seed is sown and then be completely available for use of that crop. They may spend a dollar to save ten cents' worth of time and interest, and at the end of the year leave the land in worse condition than they found it at the beginning. Of course, the manufacturer caters to this demand. For example, he takes one ton of rock phosphate worth \$4, adds to it one ton of sulfuric acid (oil of vitrol) worth \$12, and he then has two tons of an acid phosphate which sells in Illinois for about \$18 a ton, or \$36 for the two tons of product containing no more phosphorus than is contained in one ton of the original rock phosphate which could be delivered in Illinois for about \$7, or for one-fifth of the cost of the manufactured product. Of course the manufacturer must have pay for handling the sulfuric acid, for mixing it with the rock, and for bags and freight for two tons of material which he is compelled to handle.

If it is true that the farmers of the eastern and southern states can use this high-priced acid phosphate in a hand-to-mouth way, buying more or less nitrogen and potassium at the same time, and still make some profit on lands which are poorer than Illinois soils in all other elements than phosphorus, it is certainly highly probable that Illinois farmers could profitably supplement their farm manure and clover fertilizers with steamed bone meal, or natural

rock phosphate, neither of which can ever injure the soil in the least; and thus by applying large amounts of low-priced phosphorus fertilizers they would cause the productive capacity of the land to gradually increase instead of allowing it to slowly decrease, as under the present system of farming.

4. REGARDING POTASSIUM.

If a soil is rich in all elements of plant food except potassium, that element can be supplied with marked profit, either in the form of potassium chlorid (commonly but incorrectly called "muriate of potash") or potassium sulfate or kainit. The potassium chlorid contains about 42 per cent. of the element potassium, and sells at about \$50 a ton in Chicago. The potassium sulfate contains about 40 per cent. of potassium, but it sells for about \$55 a ton, the sulfate being somewhat more agreeable to handle than the chlorid and it is also preferred for use with some particular crops not grown in this State. Kainit is a crude potash mineral containing about 10 per cent. of potassium. It sells for about \$16 a ton. It will be seen that potassium chlorid is somewhat the cheapest form of the element potassium, although kainit gives very good results and is very largely used where potassium is the only element required. (Potassium is usually sold under the name of potash, a compound of potassium and oxygen containing 83 per cent. of the element potassium. If the element is worth 6 cents a pound, the compound called potash is worth about 5 cents.)

5. REGARDING FARM MANURE.

Manure is a complete fertilizer; that is, it contains some of all of the elements of fertility; but manure is not a well balanced fertilizer, because it contains too little phosphorus, much of the phosphorus being retained in the bones of the animals, while the bedding or litter is usually poor in that element (see Table 2 for phosphorus content of straw and corn stalks). Manure does contain a small amount of phosphorus, but it is much more valuable for the potassium and nitrogen which it contains and also for the humus, or organic matter, which it adds to the soil, and sometimes for the soil bacteria which it also supplies to the land. Farm manure always has been, and without doubt always will be, one of the principal materials used in maintaining the fertility of Illinois soils; but, as a rule, it is not well balanced and there are some things which it cannot do. For example, it cannot correct an acid soil and it cannot maintain the supply of phosphorus in the soil unless much more manure is used on a given farm than can be

made from the crops produced on that farm alone. (At the full market price for phosphorus, 12 cents a pound, a ton of fresh manure is worth about 24 cents for its phosphorus content.) As a very general rule, farm manure should not be replaced in maintaining or increasing the fertility of the soil, but if necessary it should be supplemented,—by lime and by some form of phosphorus, as bone meal or rock phosphate. On some few soils, however, such as peaty lands, the use of farm manure may well be entirely replaced by the use of potassium fertilizers, as will be shown later. (See Table 6—peaty swamp soil.) Peaty soils contain an abundance of both nitrogen and humus, the two constituents for which manure is most valued. Manure is most useful on soils which are deficient in humus, upon the supply of which the soil is largely dependent for its capacity to absorb and retain moisture and thus to resist drouth. As a source of humus, however, manure may well be supplemented, and if necessary, entirely replaced by any other organic matter, including green manure crops, although, if heavy crops of green manures are added to the soil, care must be taken that the soil contains sufficient lime to keep it sweet, as

TABLE 2. FERTILITY IN MANURE, ROUGH FEEDS, AND FERTILIZERS.

Name of material.	Pounds per ton.			Value per ton.			
	Nitro- gen.	Phos- phorus.	Potas- sium.	Nitro- gen.	Phos- phorus.	Potas- sium.	Total value.
Fresh farm manure	10	2	10	\$ 1.50	\$.24	\$.60	\$ 2.34
Corn stover.....	16	2	17	2.40	.24	1.02	3.66
Oat straw.....	12	2	20	1.80	.24	1.20	3.26
Wheat straw.....	10	2	17	1.50	.24	1.02	2.76
Clover hay.....	40	5	30	6.00	.60	1.80	8.40
Cow pea hay.....	43	5	33	6.45	.60	1.98	9.03
Alfalfa hay.....	50	4	24	7.50	.48	1.44	9.42
Dried blood.....	280			42.00			42.00
Sodium nitrate....	310			46.50			46.50
Ammonium sulfate..	400			60.00			60.00
Raw bone meal....	80	180		12.00	21.60		33.60
Steamed bone meal	20	250		3.00	30.00		33.00
Acidulat'd bone meal	40	140		6.00	16.80		22.80
Slag phosphate.....		160			19.20		19.20
Rock phosphate....		250			30.?		30.?
Acid phosphate.....		125			15.00		15.00
Potassium chlorid... (muriate of potash.)			840			50.40	50.40
Potassium sulfate... (sulphate of potash.)			800			48.00	48.00
Kainit			200			12.00	12.00
Wood ashes'..... (unbleached)		10	100		1.20	6.00	7.20

1. Wood ashes also contain about 1000 pounds of lime carbonate per ton.

considerable acidity is produced by the decomposition of the fresh organic matter.

Table 2 gives the average quantities in pounds per ton of the different valuable elements of plant food contained in ordinary manure, in litter and rough feeds, and in some fertilizers.

It will be observed that a ton of the best steamed bone meal or a ton of the richest rock phosphate contains about 125 times as much phosphorus as a ton of fresh manure; while a ton of potassium chlorid, 80 per cent. pure, as commonly sold on the market, under the name of "muriate of potash", contains about 84 times as much potassium as a ton of manure.

By referring to Table 1 and Table 2, it will be seen that about two tons of fresh manure would furnish as much potassium as 100 bushels of corn would remove from the soil, while the 100 bushels of corn would remove 4 times as much phosphorus and 5 times as much nitrogen as the two tons of manure would furnish. Thus for our common system of harvesting corn (leaving the stalks in the field) we have the problem in pounds of fertility as follows:

POUNDS OF FERTILITY.

	Nitrogen.	Phosphorus.	Potassium.
100 bushels corn contain	100	17	19
2 tons farm manure contain....	20	4	20
Difference.....	80	13	
100 pounds bone meal to balance.....		13	
Balance still due..	80		

Of course the balance of nitrogen can be most economically supplied by the growing of leguminous crops, but unless one has unlimited quantities of manure he will find it a wise and profitable practice on soils needing phosphorus to balance his ration for corn by applying bone meal or rock phosphate with his manure and clover fertilizer. The Ohio Experiment Station has shown that the value of manure is increased 30 per cent. by adding to it a small amount of fine ground rock phosphate, even after paying the cost of the rock phosphate; and this value has been measured in actual increase in crop yields.

The rock phosphate or bone meal can be mixed with the manure as it is made, using about one pound for each animal per day or it can be spread on the field with the manure, preferably perhaps with a manure spreader; or it can be sowed by itself with an end gate seeder.

As already stated the fertility of the soil can be maintained or even increased by the use of farm manures alone, but much more

manure will be required than can be produced from the crops grown on the farm. In the famous experiments which have been conducted for more than sixty years at Rothamsted, England, the average yield of wheat has been maintained, by use of farm manures alone, at more than thirty bushels of wheat per acre. But how has this been done? *By applying 14 tons per acre of good barn yard manure every year.* But who can make 14 tons of good manure from the refuse left from a 30-bushel crop of wheat?

It is an easy thing, and usually it is a popular thing, to say that farm manure and legumes are the only fertilizers you need to use, and that the purchase of any other fertilizer is a waste of money; but I would indeed be a traitor to Illinois Agriculture if I allowed myself to spread abroad this popular opinion.

I know and you know, that even the average Illinois live stock farmer not only does not and cannot apply 14 tons of manure per acre every year, but as a rule he cannot make an application of eight tons of manure per acre more than once in four years; while as a matter of fact what he actually does do is usually to scatter the manure over a few thin places near the barn and give the remainder of his farm an occasional "rest" by pasturing.

Whenever you can make two minus one equal two, then you can maintain the fertility of the soil without putting back as much plant food as is taken off. The merchant buys and sells and buys again, but the farmer usually sells and sells and sells, until he is practically "sold out." Then he "goes West," and with him "Westward the course of Empire takes its way." Is not this the history of the civilized world?

THE APPLICATION OF MINERAL FERTILIZERS.

There is one general rule to be observed in the application of fertilizers; namely, *thoroughly mix them with the soil.* Apply them uniformly and make them a part of the soil itself,—by disk-ing, dragging, plowing, harrowing, cultivating,—any way to get them thoroughly incorporated with the soil. At least one year's time will usually be required to fully produce this effect.

I am often asked if it is a good plan to apply the fertilizer in the hill with corn. This is very poor practice. The effect of such an application is usually to over stimulate the early growth of the corn, meanwhile the roots do not properly develop and spread through the soil in proportion to the growth above ground, and consequently when the drier season comes on and earing time approaches, the corn fertilized in the hill suffers more than the unfertilized corn and frequently produces a smaller yield of ears at harvest time.

People sometimes ask when is the best time to apply fertilizers. I think almost any time will do well, if it is about a year before you expect marked results. Fertilizers may well be applied whenever you can get on the land and are not too busy with other work. Probably as good a practice as any is to apply them in the fall or spring and then cultivate the land in corn and follow the next year with oats and clover. The effect should be apparent on the clover and it should be marked on a succeeding corn crop.

Heavy applications; that is, from 600 or 800 pounds to one or two tons per acre, may well be applied broadcast as uniformly as possible with a shovel or preferably with a manure spreader, by putting in the box a uniform layer of the material, which may well be applied with the manure. Lighter applications may be made with an end-gate seeder or with a fertilizer drill. For lime or heavy applications of rock phosphate, I would advise using the manure spreader; for bone meal or potash salts, or moderate applications of rock phosphate (300 to 600 pounds), use the end gate seeder, or fertilizer drill, or even a good force-feed grain drill. In case both phosphorus and potash salt need to be applied to the soil, which is rarely the case, a force-feed grain drill with fertilizer attachment is probably the best implement to use, running the bone meal or rock phosphate through the grain box and the potash salt through the fertilizer box.

On all our soil experiment fields in different sections of Illinois we are using fertilizer disk drills made by the Superior Drill Company, of Springfield, Ohio. This implement not only applies two kinds of fertilizers at once, but it applies each of them at any rate desired and with perfect uniformity; and, at the same time, it cultivates the soil by disking. It enables the farmer to use raw materials instead of ready mixed fertilizers and thus saves the cost of mixing by the fertilizer manufacturer, which usually amounts from \$4 to \$8 per ton. If only one element of plant food needs to be applied, as is usually the case, the grain box may be used at the same time, (as in sowing wheat or oats), and, of course, grass or clover seed may be sowed through the grass seeder attachment if desired. Somewhat similar implements are manufactured by other companies. The end-gate seeder is also very satisfactory.

Table 3 shows the results of experiments which have been conducted by the Ohio Experiment Station and the Maryland Experiment Station, with several different forms of phosphorus which I believe could profitably be used on some Illinois soils.

The soil experiments carried on during the past twelve years by the Ohio Experiment Station, under the management of Direc-

TABLE 3 (A)—OHIO SOIL EXPERIMENTS.

AVERAGE OF RESULTS FROM WOOSTER AND STRONGSVILLE FIELDS.

(Increase only—bushels per acre.)

Plot No.	Form of phosphorus (with nitrogen and potassium.)	Crop grown.	1st year increase.	2nd year increase.	3rd year increase.
26	Bone meal	Corn	2.42	4.16	6.46
29	Slag phosphate	Corn	3.51	9.32	13.19
30	Tankage	Corn	3.89	14.44	10.38
	Average		3.27	9.31	10.01
26	Bone Meal	Oats	6.44	9.45	14.57
29	Slag phosphate	Oats	5.74	7.98	18.67
30	Tankage	Oats	3.71	7.12	10.93
	Average		5.29	8.18	14.73
26	Bone meal	Wheat	1.11	8.24	8.05
29	Slag phosphate	Wheat	2.21	11.32	8.43
30	Tankage	Wheat	.66	9.94	4.69
	Average		1.33	9.84	7.06

(B)—MARYLAND SOIL EXPERIMENTS.

(Increase only,—bushels per acre.)

Plot No.	Form of phosphorus (with legume and potassium)	Increase, corn.			Wheat.
		1895	1896	1897	1899
8	Raw bone meal	1.6	4.4	12.5	13.8
9	Slag phosphate	1.0	3.5	9.0	14.1
11	Ground S. C. rock phosphate	3.0	6.2	11.3	9.1
12	Florida soft rock phosphate	4.6	7.7	13.7	10.1
	Average	1.3	5.5	11.6	11.8

tor C. E. Thorne, are probably the most valuable series of soil investigations by plot experiments which have been conducted in America. In my judgement the value of these experiments to American agriculture is second only to that of the original and now world-renowned investigations of Lawes and Gilbert, which have been in progress during the past sixty years at Rothamsted, England. The Ohio experiments are of especial value to Illinois agriculture, because they have been conducted on soils which in many respects are similar to Illinois soils.

All of the experiments reported in Table 3 show that the full effect of these fertilizers is not produced till the second or third year, and the limit of increase may even then be due to an insufficient supply of nitrogen. In the Ohio experiments a five-year rotation of corn, oats, wheat, clover, and timothy was practiced, and 75 pounds of commercial nitrogen were added; but other experi-

ments in the series (not shown here) prove that still heavier applications of nitrogen further increased the yield, thus indicating that a more liberal use could well have been made of leguminous crops or farm manure. In the Maryland experiments the entire supply of nitrogen, aside from the nitrogen in the soil, was furnished by crimson clover grown in the corn as a "catch" or companion crop; and it is not improbable that the applications of phosphorus would have produced a much larger increase if a more abundant supply of nitrogen had been provided.

After ten years of investigations, Director Thorne reports that slag phosphate gives better results on Ohio soils than any acidulated phosphate. Untreated rock phosphate was not used in the regular series of Ohio experiments, but it has been used for a shorter time in connection with farm manure, and as stated above its use has increased the value of the farm manure 30 per cent. after paying the total cost of the rock phosphate. It is certainly of much interest to observe that in the Maryland experiments the effect of the untreated rock phosphate from South Carolina and from Florida compared very favorably with that of the slag phosphate. About 500 pounds of ground rock phosphate per acre were applied each year.

All of these experiments strongly indicate that fine ground rock phosphate, as well as bone meal, will be a valuable form of phosphorus for Illinois soils.

We already have soil experiments in progress in Illinois to determine positively the value of the different forms of lime and of phosphorus on different soils in the State, but you will bear in mind that it is only 20 months since the first appropriation was made for investigating the soils of this State and, of course, our results from field experiments are very meager.

Table 4 is believed to show approximately the composition of the principal types of soil in each of the different large soil areas in the State, as shown in the accompanying general survey soil map of Illinois, and briefly described on the following pages.

It should be understood that the divisions shown on the map are not soil types but soil areas, based largely upon the original formation of the soil, and that the composition given and the description and discussion which follow apply only to the principal type of soil found in each area. (In the detail soil survey which has already been begun by the Illinois Experiment Station, with the coöperation of the United States Government, every type of soil, even down to 10-acre fields, is being mapped and analyzed.)

EXPLANATION OF MAP.

According to geological investigation there have been three different times when glaciers, or ice sheets, have covered more or less of the State of Illinois, in consequence of which nearly all of the surface of the State is covered by soils of glacial formation. The first glacier covered all of Illinois as far south as the Ozark Spurs, excepting a part of what is now called Calhoun County and a small area in the northwest corner of the State. The area where the drift, or debris, left from this first glacier still remains the surface is called the Illinoisan Glaciation. For our purpose in soil investigation we divide this Illinoisan Glaciation into three areas, because of the marked difference in the agricultural values and properties of the soil. These three areas we call the lower Illinoisan Glaciation, the Middle Illinoisan Glaciation, and the Upper Illinoisan Glaciation, each of which will be more fully described later.

The second glacier covered only three or four tiers of counties from the north line of the State, but the area did not include the extreme northwest corner of the State. Where the drift from this second glacier is now the surface, it is termed the Iowan Glaciation.

The third and last glacier covered approximately the northeast one-quarter part of the State and this area is called the Wisconsin Glaciation.

According to the formation we have about ten large soil areas in the state, although each of these areas may contain several different types of soil:

1. Unglaciaded Area—Chiefly in seven southern counties.
2. Illinoisan Moraines—Chiefly ridges near Kaskaskia river.
3. Lower Illinoisan Glaciation—Chiefly between Wabash and Kaskaskia rivers.
4. Middle Illinoisan Glaciation—Chiefly between Kaskaskia and Illinois rivers.
5. Upper Illinoisan Glaciation—Chiefly between Illinois and Mississippi rivers.
6. Iowan Glaciation—Chiefly in Stephenson, Winnebago, Boone, Carroll and Ogle counties.
7. Wisconsin Moraines—Chiefly broad ridges and rolling prairie in northeast quarter part of the State.
8. Wisconsin Glaciation—Chiefly level prairie in northeast quarter part of the State.
9. Loess Soils—Chiefly narrow strips of upland (5 to 15 miles wide) along Mississippi, Illinois and Wabash rivers.
10. Sand, swamp areas, and bottom lands, scattered over the State.

TABLE 4.—FERTILITY IN ILLINOIS SURFACE SOILS.

Pounds per acre,—tentative data.

No.	Principal type of soil in the area.	Nitrogen (in 7 in.)	Phosphorus (in 7 in.)	Potassium (in 7 in.)	Lime required (in 15 in.)
1	Unglaciaded hills.....	1,000	1,000	5,600	900
3	Lower Ill. Gla. prairie.....	2,800	600	4,200	2,400
4	Middle Ill. Gla. prairie....	5,000	1,000	8,400	200
5	Upper Ill. Gla. prairie.....	5,400	1,400	5,600	150
6	Iowan Glaciation prairie...	4,300	1,100	7,400	300
7	Wisconsin Moraine soil...	5,000	1,200	7,400	200
8	Wisconsin Gla. prairie....	6,200	1,600	8,800	00
9	Loess soil, old.....	1,800	800	5,600	300
10 (a)	Sand soil	1,100	300	2,400	300
10 (b)	Peaty soil.....	67,000	2,000	1,200	600
	Av. U. S. fertile soil.....	5,600	2,000	6,600	00
	German fertile soil.....	6,000	2,000	4,000	00
	Ohio soil, Strongsville, O..	4,400	1,400	3,200	(?)

NOTE.—The degree of acidity in the respective subsoils of the above named types of soil is as follows, by number:

Subsoil of No. 1 is strongly acid; No. 3 is very strongly acid; No. 4 is not acid; No. 5 is not acid; No. 6 is moderately acid; No. 7 is not acid; No. 8 not acid and usually contains plenty of lime carbonate; No. 9 is slightly acid; No. 10 (a) is slightly acid; No. 10 (b) is sometimes acid, but usually not acid, and frequently contains much lime carbonate, even in the surface soil.

It should be stated that several of these averages are based upon the analyses of a very few samples of soil (which however are believed to be truly representative of the type.) Consequently these averages should be considered as tentative and subject to revision upon the accumulation of additional data. The data given for the "Average United States fertile soil" are the average of six averages each of which represents as nearly as can be ascertained the average composition of the fertile soils of a state. These six states include Colorado, North Dakota, Minnesota, Michigan, Ohio, and Massachusetts, and the general average here given really represents several hundred separate analyses. These figures are also tentative and subject to revision as more data accumulate regarding the composition of the normal fertile soils of America, but this average is probably the best American standard we now have as to what is, and should be, the composition of a soil which needs no fertilizer of any kind to enable it to produce maximum crops.

The data given for the "German fertile soil" were recently furnished by Professor F. Wohltmann, Director of the Institute for Soil and Plant Investigations, connected with the Agricultural Academy of Bonn-Poppelsdorf, Germany. These numbers represent the standard which Professor Wohltmann has adopted for the composition of a soil which needs no fertilizer of any kind. It is interesting to observe that these two "standards" which were obtained from entirely separate and independent sources are so nearly alike. The amount of phosphorus is exactly the same in each "standard," and it is somewhat surprising that Professor Snyder reported several years ago this same amount for the average phosphorus content of 200 fertile soils of Minnesota.

Probably we cannot do better at the present time than to adopt the German standard and consider that a normal fertile soil should contain 6,000 pounds of nitrogen, 2,000 pounds of phosphorus, and 4,000 pounds of potassium per acre, in the surface soil to a depth of 7 inches. And certainly no lime should be required to a depth of 15 inches.

In adopting this standard we must also assume that the soil is in good physical condition and that it is normal in other respects; namely, that with increasing depth, the nitrogen decreases rapidly, the phosphorus decreases slowly, and the potassium and lime slowly increase in amount, which are the actual conditions in nearly all normal soils. Furthermore, we should bear in mind, this "standard" applies more particularly to grasses and cereal grain crops. For legumes the soil need not furnish any nitrogen, if it is properly provided with phosphorus, potassium, lime, and suitable bacteria. On the other hand, for potatoes, root crops, fleshy fruits, etc., the potassium content should probably be much higher than that given in the "standard."

There are two methods by which we can obtain some idea of the possible productive capacity of soils from a knowledge of their composition: First, by estimating the amounts of plant food which are likely to become available to the crops each year and comparing these amounts with the amounts actually required for the production of crops. Second, by comparing the soil with some standard, or normal, fertile soil.

(1). By the first method we may assume, for example, that about one per cent. of the total stock of phosphorus and potassium and two per cent. of the nitrogen contained in the surface soil may become available for the use of plants each year. By pointing off two decimal places in Table 4, and multiplying the nitrogen by

two, we then have the numbers which represent these percentages of plant food in the soils (See Table 5). If this assumption were correct then the black prairie soil of the Wisconsin Glaciation would give up 16 pounds of phosphorus, or as much as is contained in 94 bushels of corn; while the white clay soil of the Lower Illinoisan Glaciation would give up 6 pounds of phosphorus, or enough for 35 bushels of corn. Of course, this is at best only an approximation, but nevertheless it serves to illustrate with some degree of accuracy an absolute fact; namely, that, at the most, it is only a small percentage of the total stock of fertility that becomes available to crops during any one season. This percentage will certainly vary somewhat with the season and it will vary with different elements and with different soils, but it is altogether likely that the richer soils will yield a larger percentage of their large stock than the poorer soils will of their small stock. In other words, the soil of the Wisconsin Glaciation, instead of 16 pounds of phosphorus, may give up 18 or 20 pounds, while the soil of the Lower Illinoisan Glaciation instead of 6 pounds may give up only 4 or 5 pounds of phosphorus.

TABLE 5. APPROXIMATE ANNUALLY AVAILABLE FERTILITY IN ILLINOIS SURFACE SOILS,—ROUGHLY ESTIMATED.

Pounds per acre.

Principal type of soil in the area.	Nitrogen (in 7 in.)	Phosphorus (in 7 in.)	Potassium (in 7 in.)
Unglaciaded hills	20	10	56
Lower Illinoisan Glaciation prairie.....	56	6	42
Middle Illinoisan Glaciation prairie.....	100	10	84
Upper Illinoisan Glaciation prairie.,....	108	14	56
Iowan Glaciation prairie..	86	11	74
Wisconsin Moraine soil.....	100	12	74
Wisconsin Glaciation prairie.....	124	16	88
Loess soil, old.....	36	8	56
Sand soil.....	22	3	24
Peaty soil.....	1340*	20	12
Av. U. S. fertile soil.....	112	20	66
German fertile soil.....	120	20	40
Ohio soil, Strongsville, O.....	88	14	32
Contained in 100 bu. of corn.....	100	17	19

*Peaty soils decompose very slowly, consequently a very much smaller amount of nitrogen would become available than is here indicated.

In trying to study and to understand the subject of soil fertility and the meaning of soil analyses, it is exceedingly useful and helpful to fix in mind the fact that only a small percentage of the total stock of fertility contained in the soil ever becomes available to plants during any one season. As a general average, 1 per cent. is perhaps approximately correct for phosphorus and potassium; while probably 2 per cent. is more nearly correct for nitrogen.

Of course, we should bear in mind that there is plant food in the subsoil, but its percentage of availability is very much lower than that of the plowed soil, and in many cases, especially with shallow rooting annual plants and cultivated crops, this additional supply of plant food is doubtless fully counterbalanced by losses of plant food in drainage and surface washing.

(2). By comparing the composition of the different soils of Illinois with that of the standard fertile soils it appears that the peaty swamp soils are the only soils of the State which do not need to grow leguminous crops to maintain their supply of nitrogen, and many of the soils are markedly deficient in nitrogen. As a rule, the soils which most need to grow legumes are markedly acid and must be given an application of lime before legumes can be expected to be very successful upon them.

Perhaps the most striking fact is that none of the soils are very rich in phosphorus, while many of them are considerably below the standard fertile soil, and two or three soils of large area are markedly deficient in that element, particularly the large area of so-called white clay soil of the Lower Illinoisan Glaciation.

With the exception of the peaty swamp soil and the sand soil, all of the soils of the State are above the German standard in potassium, although the soil of the Lower Illinoisan Glaciation is but little above it and is not equal to the American average. It seems not improbable that applications of potassium might prove profitable on this soil, especially for growing such crops as apples, potatoes, sugar beets, or other crops which require large amounts of potassium; indeed, we have some evidence which strongly indicates that potassium may be profitably used even on the Wisconsin moraine soil when such crops are frequently or continuously grown on the same field.

Table 6 shows the results which have been obtained from the application of different elements of plant food to an Ohio soil whose composition is shown in Table 4.

The composition of this Ohio soil (see Table 4) shows that it is as well supplied with phosphorus as any of the Illinois soils ex-

cepting the Wisconsin Glaciation prairie and the peaty soil, while it is poorer in both nitrogen and potassium than most Illinois soils.

The results of ten years' experiments show that phosphorus has been used on this Ohio soil with very large profit while nitrogen and potassium have been applied at a marked financial loss in nearly every instance. As most of the Illinois soils are better supplied with nitrogen and potassium than the Ohio soil it seems very sure that these elements should not be purchased for use on ordinary Illinois prairie soils, unless it may be that potassium could be used with some profit for special crops such as referred to above; and, possibly, even for other crops on the Lower Illinoisan Glaciation (see Table 8). In one instance potassium was found to yield some profit when used for potatoes on the Ohio soil.

On the other hand, if applications of phosphorus are profitable on the Ohio soil, it would seem certain that they would be even more profitable on many Illinois soils, especially those which are markedly deficient in phosphorus but which are well stocked with potassium and either do have or could have abundant supplies of nitrogen if proper use were made of lime and legumes, or farm manure.

TABLE 6. SOIL EXPERIMENTS AT STRONGSVILLE, OHIO.

(Average of ten years)

(L—lime: N—nitrogen: P—phosphorus: K—potassium)

Plot No.	Plant food appl'd	Cost of fertilizer in 5 years.				Value of increase.	Net profit.	Net loss.
		N	P	K	Total.			
5	N	\$11.25			\$11.25	\$.93		10.32
2	P		2.40		2.40	12.54	10.14	
3	K			6.60	6.60	.45		6.15
6	NP	11.25	2.40		13.65	16.76	3.11	
9	NK	11.25		6.60	17.85	3.23		14.62
8	PK		2.40	6.60	9.00	12.13	3.13	
11	NPK	11.25	2.40	6.60	20.25	19.09		1.16
29*	LNPK	11.25	2.40	6.60	20.25	21.56	1.31	

Cost per pound.		Actual value of elements per pound.				
Element.	Cost.	Alone.	After N.	After P.	After K.	After 2 others.
Nitrogen.....	15c	1.2c	c	5.6c	3.7c	9.1c
Phosphorus....	12	62.7	79.2	....	58.4	79.3
Potassium.....	6	.4	2.1	.4	....	2.1
P in 29*.....	12					91.7

*In plot 29 the phosphorus was applied as slag phosphate and its higher value on this plot is undoubtedly due to the lime contained in the slag.

Table 7 gives some results from pot culture and field experiments which show (a) the value of nitrogen first, and then of phosphorus, on the old unglaciated hill soil of southern Illinois, Pulaski County, (see Plate 2); also (b) the value of phosphorus first, then of nitrogen, and then of potassium on the Lower Illinoisan Glaciation, Marion County, (see Plate 3); and, lastly, (c) the marked value of potassium on the peaty swamp soil, Whiteside County, (see Plate 4). By reference to Tables 4 and 5 it will be seen that these results are in accordance with what might be expected from the composition of these soils. (As a matter of fact, the nitrogen content of the unglaciated hill soil which was actually used in these experiments was lower than the average for that soil which is shown in Table 4, while the phosphorus in the soil used was above the average.)

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS.

Soil test No.	Kind of plant food applied.	(a) Unglaciated hill soil (N most needed).	(b) Lower Illinoisan glaciation (P most needed).	(c) Peaty swamp soil, Whiteside County (K most needed).	
		Wheat, grams.	Wheat, grams.	Ear corn, bushels.	Fodder, pounds.
1	0	3.0	11.0	0	1,000
2	L	3.9	11.6	0	800
3	LN	26.0	9.2	0	1,200
4	LP	3.3	13.6	0	2,000
5	LK	3.3	10.3	36.3	3,600
6	LNP	34.0	20.6	0	1,400
7	LNK	32.8	7.2	40.0	3,500
8	LPK	2.1	13.7	37.5	3,100
9	LNPK	34.4	26.5	60.0	4,400
10	NPK	30.6	24.5	52.5	4,750
11	0	3.0	9.9		
12	0	3.4	9.5		

(a) Compare 8 and 9 for maximum effect of nitrogen.

(b) Compare 7 and 9 for maximum effect of phosphorus.

(c) Compare 6 and 9 for maximum effect of potassium.

Table 8 shows (a) that in field experiments on the soil of the Lower Illinoisan Glaciation (Perry County) phosphorus increased the yield of wheat from 13.1 to 16.5 bushels per acre, while the addition of potassium further increased the yield to 20.3 bushels; (b) that on the soil of the Middle Illinoisian Glaciation (St. Clair County) phosphorus increased the yield of wheat from 17.1 to 26.4 bushels, while with potassium added to the phosphorus the yield was still further increased to 33.8 bushels, as the average of three

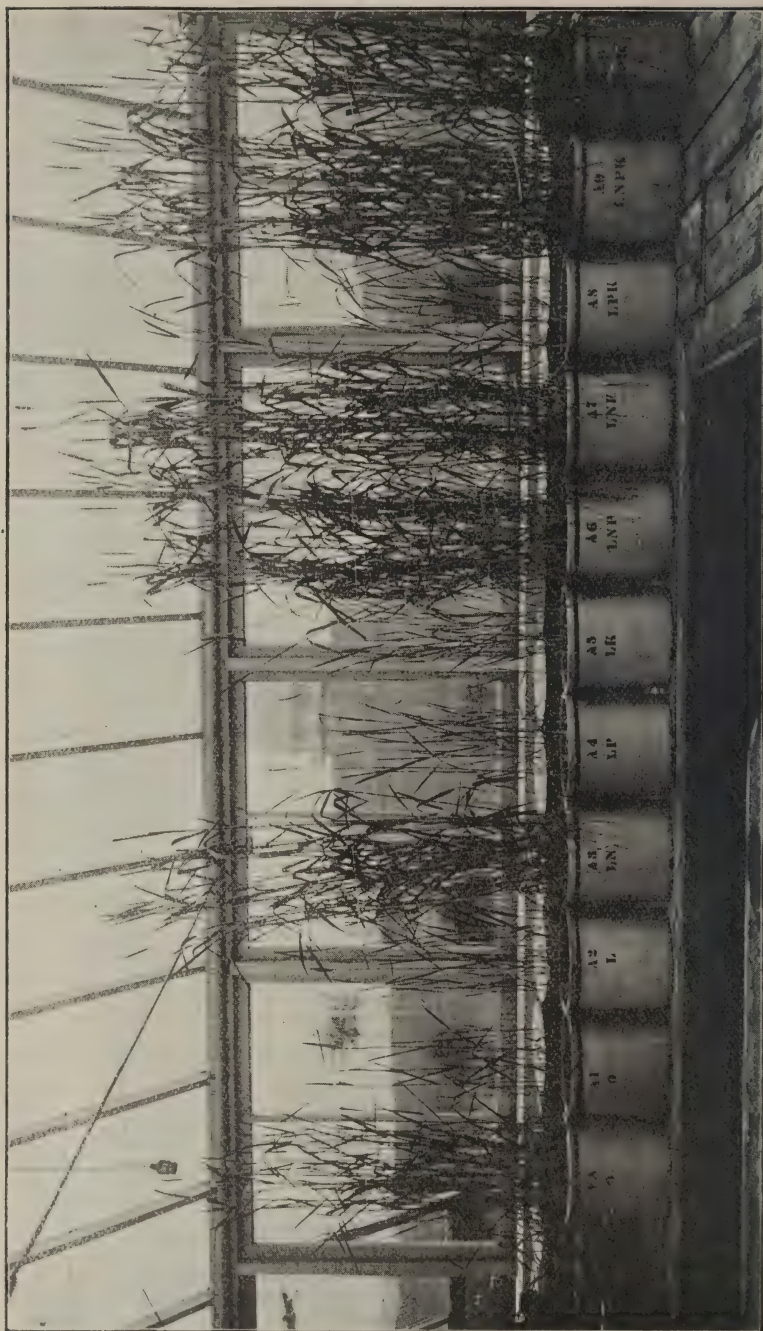


PLATE 2.—Wheat on Unglaciaded Soil (Pulaski County Hills) Effect of Nitrogen.

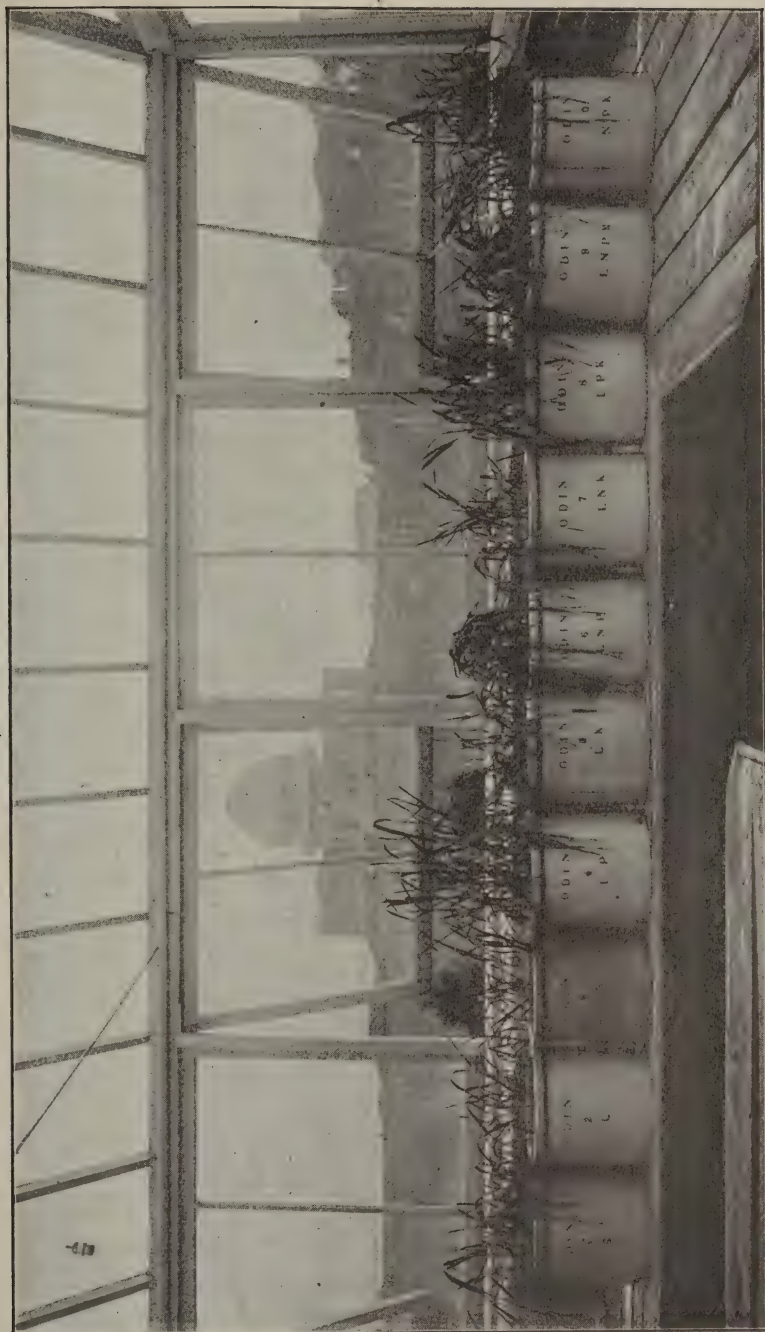


PLATE 3.—Wheat on Lower Illinoisan Glaciation Soil (Marion County Prairies) Effect of Phosphorus.



PLATE 4.—Corn on Swamp Soil (Whiteside County "Poison" Land) Effect of Potassium.

quite discordant results; and (c) that on the Wisconsin moraine Soil on the Experiment Station farm at Urbana (Champaign County) applications of lime, of both lime and phosphorus, and of lime, phosphorus, and potassium, altogether, produced very beneficial and profitable results. The phosphorus was applied in the form of bone meal at the rate of 320 pounds per acre. Potassium chlorid was applied at the rate of about 160 pounds per acre (a double application of potash salt was given to the sugar beets on plots 8, 9, and 10). It should be stated that two crops of sugar beets had been produced on this field previous to 1892. No fertilizers had ever been applied to any of these plots before the fall of 1901. The average of three years' previous corn crops, is given in the last column and shows that these plots were exceedingly uniform in their productive capacity previous to the application of fertilizers for the 1902 crop.

TABLE 8. CROP YIELDS IN SOIL EXPERIMENTS.

Soil test No.	Kind of plant food applied for 1902.	(a) Lower Illinoisian glaciation.	(b) Middle Illinoisian glaciation.	(c) Wisconsin moraine.	
		Wheat, bushels, 1902.	Wheat, bushels, 1902.	Sugar beets, tons, 1902.	Corn, bu., average of 3 years.
1	o	12.8	19.7	9.23	66.8
2	o	12.4	15.2	7.80	67.0
3	o	12.4	15.3	9.53	66.3
	Average	12.5	16.7	8.85	66.7
4	L	13.3	17.7	13.14	71.8
5	L	12.9	16.5	14.52	71.7
	Average	13.1	17.1	13.83	71.8
6	LP	16.9	24.7	17.21	68.0
7	LP	16.1	28.0	18.22	67.4
	Average	16.5	26.4	17.72	67.7
8	LPK	20.8	29.8	21.83	68.7
9	LPK	19.4	31.7	24.08	67.4
10	LPK	20.8	39.8	23.86	64.7
	Average	20.3	33.8	23.25	66.9

NOTE.—These experiments will ultimately include the growing of leguminous catch crops (on plots 2, 4, 6, and 8), and the application of farm manure about once in four years (on plots 3, 5, 7, and 9) and the effect of this additional treatment will be ascertained from subsequent crop yields.

(b) The particular soil used for this series of experiments was found to contain much less potassium than is found in the average soil of this type; that is, the Middle Illinoisian Glaciation prairie.

The sugar beets were worth about \$4.60 a ton and the total cost of the fertilizers on plots 8, 9, and 10 was about \$12 per acre. Of course, legumes and manure are to be used on some of these plots in connection with the use of the mineral elements of plant food and probably we shall have more marked results after one or two crop rotations.

Lime is not expected to be of much direct benefit to wheat, but it should benefit legumes.

TENTATIVE RECOMMENDATIONS AND SUGGESTIONS FOR DIFFERENT TYPES OF SOIL, REPRESENTING LARGE AREAS OF ILLINOIS LANDS.

The following kinds of treatment recommended, or suggested for trial, for the soils of Illinois, are, as a rule, to be considered in addition to the use of the manure produced on the farm. I certainly ask for some measure of charity from Illinois farmers in their consideration of the recommendations which are here made for maintaining and increasing the productive capacity of Illinois soils. I am sure you will appreciate the fact that to investigate the soils of a state like Illinois is a task of no small magnitude. Bear in mind, for example, that the northern boundary of Illinois almost coincides with the southern boundary of Vermont and New Hampshire, while the southern point of Illinois is only 30 miles north of the southern boundary of Virginia. Boston, Massachusetts, and Richmond, Virginia, both fall within the latitude of the State of Illinois. This range of latitude includes Massachusetts, Connecticut, New Jersey, Delaware, Maryland and Virginia.

You will also bear in mind that less than two years have elapsed since these investigations began. We certainly realize that, as yet, our information is meager; our results are few; and the conclusions drawn are tentative. They apply more strongly to old worn soils than to new lands. These recommendations and suggestions are made with the hope that they may be given careful trials at least on a few acres of land and for at least five years, and the results compared with control or check plots which are treated in the ordinary way. In making these trials, don't try to compare clover with lime, but compare clover with lime *and* clover both together; and don't compare manure with bone meal, but compare manure with manure *and* bone meal both together. For use in traveling you would not compare a horse with a carriage, but you would compare a horse with a horse *and* carriage.

While the recommendations as to treatment are very general, it is believed that when supplemented by good sense and general knowledge, more than one-half the farmers of Illinois can get some ideas or suggestions which they will be able to see are applicable to the actual soils they are cultivating. Nearly every farmer recognizes different types of soil, and, as a rule, farmers know which is the principal or commonest type of soil in their section of the State, whether they live in Johnson, Clay, Sangamon, Warren, Stephenson, McHenry, or Douglas county, or in any other county in any of the large soil areas of the State.

All of the recommendations are meant only to supplement good farm practice. Always make use of farm manures, grow clover or other legumes, prepare the ground well, plant good seed, and practice good cultivation; but in addition to all of this, try the effect of applying lime, phosphorus, or potassium, in accordance with the composition of your type soil and the needs of the crop (See Table 1). Where a liberal use of leguminous crops is recommended, sow cow peas or soy beans or vetch in the corn at the last cultivation; sow clover or vetch in the oats and wheat or sow cow peas, soy beans, or vetch as soon as possible after the oats and wheat are harvested. In addition to this a full crop of legumes should be grown once in about 3 to 5 years.

1. UNGLACIATED SOIL.

Principal type: Red clay hill soil, common in the following counties: Union, Johnson, Pope, Hardin, Alexander, Pulaski and Massac.

Treatment recommended: 1,500 to 2,000 pounds of limestone per acre and a liberal use of leguminous crops as catch and cover crops and in rotations. Additional treatment suggested for trial; 200 pounds bone meal (or 500 pounds rock phosphate*) per annum.

2. ILLINOISAN MORAINES.

(Not yet investigated.)

3. LOWER ILLINOISAN GLACIATION.

Principal type: "White clay," prairie soil, common in the following counties: Fayette, Effingham, Jasper, Marion, Clay, Richland, Washington, Jefferson, Wayne, Perry, Franklin, Hamilton, and to some extent in nearly all adjoining counties.

Treatment recommended: 1 to 2 tons limestone per acre and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of leguminous crops as catch and cover crops and

*Until we have more definite information on the subject, rock phosphate should not be substituted for bone meal, excepting, perhaps, on soils rich in organic matter, or in connection with a liberal use of leguminous green fertilizers or farm manure, or both.

in rotations. Additional treatment suggested for trial : 100 to 200 pounds potassium chlorid or potassium sulfate especially for potatoes, root crops, and orchards.

4. MIDDLE ILLINOISAN GLACIATION.

Principal type : Brown prairie soil, common in the following counties: Cass, Menard, Logan, Scott, Morgan, Sangamon, Greene and in parts of Macoupin, Jersey, St. Clair, Clinton, Bond, Montgomery, Christian and Macon.

Treatment recommended: 500 pounds limestone per acre, and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of legumes.

5. UPPER ILLINOISAN GLACIATION.

Principal type: Dark brown prairie soil, common in the following counties: Mercer, Henry, Stark, Warren, Knox, Peoria, Hancock, McDonough, Fulton, Schuyler, and in parts of Adams, Brown, and Pike.

Treatment recommended : Liberal use of leguminous crops. Additional treatment suggested for trial : 500 pounds limestone and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum.

6. IOWAN GLACIATION.

Principal type: Brown rolling prairie soil, common in the following counties: Stephenson, Winnebago, Carroll, Ogle, and in parts of adjoining counties.

Treatment recommended : 500 pounds limestone per acre, and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of legumes, as catch and cover crops and in rotations.

7. WISCONSIN MORAINES.

Principal type: Dark brown rolling prairie soil, common in the following counties: McHenry, Lake, DeKalb, Kane, Cook, DuPage, Will, Kendall, LaSalle, Livingston, Ford, and in parts of Bureau, Marshall, Tazewell, McLean, Dewitt, Champaign, Vermilion, Macon, Shelby, Coles and Edgar.

Treatment recommended: 500 pounds limestone per acre, and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of legumes, as catch and cover crops and in rotations.

8. WISCONSIN GLACIATION PRAIRIE.

Principal type: Black level prairie soil, common in the following counties: DeKalb, Kane, Bureau, LaSalle, Kendall, Grundy, Will, Kankakee, Putnam, Marshall, Woodford, Livingston, Iroquois, Tazewell, McLean, DeWitt, Piatt, Champaign, Vermilion, Macon, Moultrie, Douglas, Coles, Edgar, and in parts of Ford, DuPage, Cook, and Lake.

Treatment recommended: Legumes in crop rotation. Additional treatment suggested for trial: 200 pounds bone meal (or 500 pounds rock phosphate) per annum, and also, on old worn soil, or slightly rolling land, 500 pounds limestone per acre.

9. LOESS SOIL.

Principal type: Light brown rolling upland soil, containing some very fine sand, common along the Mississippi, Illinois, and Wabash rivers, usually occupying a strip of upland 5 to 10 miles wide.

Treatment recommended: 500 pounds limestone per acre, and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of legumes as catch and cover crops and in crop rotations.

10. (a) SAND SOILS.

Common in parts of Whiteside, Lee, Henry, Tazewell, and Mason counties and in some bottom lands along Mississippi river.

Treatment recommended: 200 pounds bone meal (or 500 pounds rock phosphate) per annum and liberal use of barn yard manure. Additional treatment suggested for trial: 500 pounds of limestone per acre, and then 100 pounds potassium chlorid per annum and a liberal use of legumes.

10. (b) PEATY SWAMP SOILS.

Common in parts of McHenry, Kane, Whiteside, Lee, Henry, Bureau, Kankakee, Tazewell, Mason, and to some extent in many other northern counties.

Treatment suggested for trial: 50 to 100 pounds potassium chlorid per acre per annum, with light dressings of farm manure if found beneficial.

In conclusion I would say that nothing else,—most emphatically nothing else,—pertaining to the business of farming compares in importance with the subject of soil fertility, and yet there is probably no subject about which Illinois farmers have been more indifferent in the past. I believe in well bred and well fed stock ;

I believe in making, saving, and using farm manures ; I believe in good cultivation ; I believe in growing the best varieties of crops ; I believe in the improvement of crops,—in the improvement of corn by breeding ; I believe in increasing the protein content of corn ; but I know that you cannot make protein without nitrogen ; I know that you cannot get nitrogen economically without legumes and bacteria ; I know that you cannot grow legumes successfully on acid soils ; and I know that a soil which gives up only 5 pounds of phosphorus per annum cannot yield 100 bushels of corn.

Last season we planted some improved seed corn on good soil at the University and it yielded 90 bushels per acre ; we planted exactly the same kind of corn on the white clay soil of the Lower Illinoisan Glaciation and it yielded less than 15 bushels per acre. This is not a difference in the variety ; it is a difference in the fertility of the soil.

On the other hand, we have obtained some striking indications of the value of plant food for making crops. For example, where we applied \$8 worth of plant food in St. Clair county, we got an increase of 16 bushels of wheat the first year ; where we applied \$12 worth of plant food on the University farm, we got an increase of 14 tons of sugar beets which were worth more than \$60 for factory use, and which we sold for \$42 for feed ; where we applied \$4 worth of plant food to the peaty swamp soil of Whiteside county, we got 36 bushels of corn for it the first year. Some of these results are striking and they may be extremes, and yet in no case have we reason to doubt their reliability. (The tabular statements show all of the variations in duplicate and triplicate results.) The experiments are conducted with the sole desire to learn the truth, to obtain results which may be obtained on any scale by any Illinois farmer who may try to practice what the experiments preach. These experiments must be continued ; the results must be verified or proven incorrect. It should be borne in mind, however, that our experiments include the use of legumes for increasing the nitrogen in the soil and that we have not yet had sufficient time to determine the effect of leguminous crops upon succeeding grain crops both with and without the addition of the other elements of plant food and with applications of manure, the above results having been obtained with the use of the mineral elements only.

One thing, however, we believe is settled ; namely, that we have discovered, proven, and demonstrated, for all time, that alfalfa can be grown successfully on Illinois soil ; that is, on soils which are not acid, which are not deficient in phosphorus, and which are

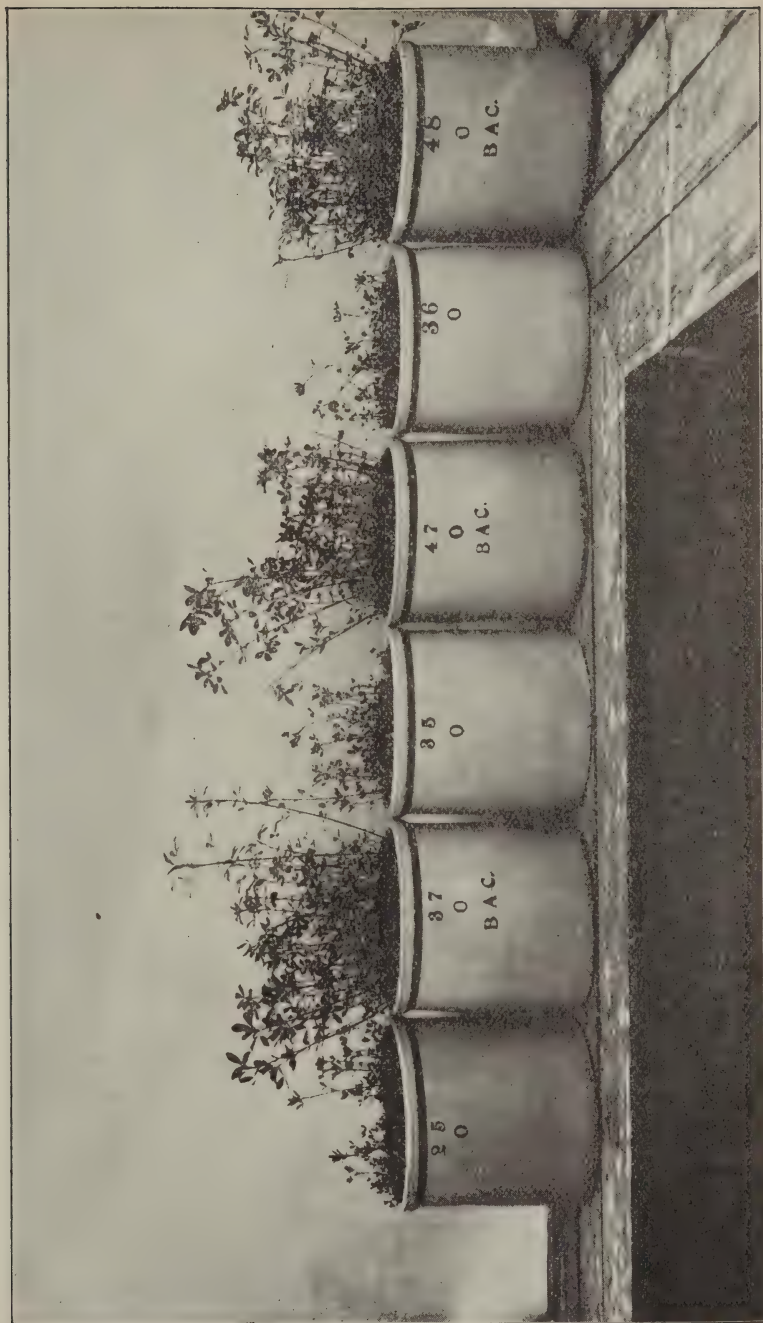


PLATE 5.—Alfalfa on Wisconsin Moraine Soil (Champaign County Rolling Prairie) Effect of Bacteria only.

inoculated or infected with the alfalfa bacteria (See Plate 5 and also Bulletin No. 76, "Alfalfa on Illinois Soil."), and these results are not considered as tentative; they are conclusive. There is no longer a question as to whether alfalfa can be grown in Illinois. The only question is, will you provide the proper conditions for it? On our own field at the University (on Wisconsin moraine soil) less than \$1 worth of lime made more than \$10 increase per acre in the alfalfa hay, and \$4 worth of phosphorus made an additional increase of \$15 worth of hay, while the presence or absence of the alfalfa bacteria made the crop a success or a failure, respectively. Alfalfa is not grown at the University alone, but it is now growing successfully (on well infected soils free from acidity) in many different places in the State, and yielding from 6 to 10 tons per acre annually.

Regarding many things pertaining to Illinois soils I do not have absolute knowledge or sufficient results to justify fixed opinions, but I do have a tentative opinion that the possibilities of financial profit to be derived from the purchase of lime and phosphorus and their application and use in connection with leguminous crops and farm manures on very large areas of Illinois soils are not yet dreamed of by the owners of Illinois lands. There are cultivated soils in the State which contain in the plowed soil only \$5 worth of phosphorus per acre, and the subsoil is no richer. That the productive capacity of these soils is limited by their low phosphorus content, is beyond question; that it could be doubled by doubling the phosphorus content, though not yet fully demonstrated, seems highly probable. That the average yield of corn on Illinois soils can be profitably increased from 37 bushels to 75 bushels per acre seems entirely possible. But what is needed? First, the careful use of farm manure, and, in addition to that, perhaps a ton or two of lime or limestone once in ten years, a generous use of phosphorus at a cost of a few cents per bushel of corn, and, ultimately, it may be, a cent or two more per bushel of corn for potassium, and then a liberal use of the element nitrogen which everywhere rests upon the surface of the earth in inexhaustible quantities. However well this may sound in theory and however feasible it may appear to be, we must bear in mind that it has not been fully proven or demonstrated; but if we can prove and demonstrate that the fertility of Illinois soil can be profitably increased and permanently maintained, then we shall accomplish a work the value of which almost passes computation and comprehension. And when I say "we," I mean every man who has assisted or is assisting in this great work. I mean Andrew S. Draper, the president of the Uni-

versity of Illinois whose intellect perceived the fact that "The wealth of Illinois is in her soil and her strength lies in its intelligent development." I mean Eugene Davenport, Dean of the College of Agriculture and Director of the Experiment Station, whose mind conceived the tremendous importance to Illinois Agriculture of the investigation and the preservation of Illinois soil, and to whom more than to any other one man credit is due that such investigations are now in progress; I mean the Illinois Farmers' Institute, the organization which now stands as a guardian over the soils of this State, and whose members asked for, and secured the initial appropriation for soil investigations; I mean the members of the Advisory Committee who serve the State without pay and give practical and valuable advice regarding these lines of work; I mean the progressive farmers with whom we are cooperating in different sections of the State, whose public spirit and whose patience and watchful care over experiments on their farms and whose kindly treatment of myself and my associates make the work a pleasure to us, and of greater value to the State; and last, but not least, I mean L. H. Smith and J. H. Pettit, J. G. Mosier and E. M. East, W. F. Pate and J. E. Readhimer, the trained and skilled analysts and the accurate field assistants who work long hours in the laboratories and in the fields and upon whose work depends the accuracy of every conclusion drawn regarding the fertility of Illinois soils and the effects of soil treatment.

But I must add one more word: If we do prove conclusively that the fertility of all of the soils of Illinois cannot be maintained by the use of legumes and the manure made from Illinois crops alone, and if we do demonstrate absolutely that the purchase of any element of plant food is necessary and profitable, then, whoever buys plant food for use on Illinois soil, let him not buy a tonic or a stimulant or a trivial amount of some highly manufactured and high priced so-called commercial fertilizer which shall only urge the soil to greater exhaustion and result in no permanent good, but let him buy liberal amounts of the real elements as near to the raw materials as possible such as fine ground limestone from the immense natural deposits of our own state, and pure phosphates such as bone meal (originally a farm product) or as fine ground rock phosphate from the very extensive phosphate mines of the southern states, and, if necessary, potassium from the abundant supplies of the German potash mines; and then let him apply at least two pounds for every pound he removes in crops; let the supply increase and not decrease; let the soils of Illinois not grow poorer but richer

and richer,—for the land's sake, for your children's sake, and for Illinois' sake.

If we do learn that this is possible, then let us have one country on earth—let us have one state in this Union, whose soils shall not be ruined and whose children shall not be left with only a memory or a tradition of the bountiful harvests of former years.

Listen: One and one-half million tons of rock phosphate is the annual production of the mines of the United States.

Listen: One million tons of this material (two-thirds of the total product) is the annual export to foreign countries.

Americans are proud today that our exports exceed the imports. Are we proud of this export trade? If there is any one factor more potent than others to finally ruin the agriculture of this state,—to reduce all our lands to the level of the worn out lands of the Eastern States and of the countries of Europe, *many of which cannot today produce their own supply of bread*,—I say if there is any one thing which shall ultimately bring this condition upon us or upon our children, I believe it is the loss of phosphorus.

I am neither sensational nor merely theoretical. If anything I am practical. Pardon me for the personal remark. The greater part of my life I have been a practical farmer,—not a “side walk” farmer, but just a plain every day farmer in plain blue overalls,—with hands which are still calloused from years of farm work.

Farm work! If working in the field from sunrise till sunset,—plowing, sowing, planting, cultivating, harvesting, stacking, threshing,—if this and the milking of 10 or 12 cows twice a day besides other “chores,” is farm work, then I have done farm work,—not merely for a month or a season, but for years.

I do not speak of this boastingly. I speak of it because I want your confidence and the confidence of the Illinois farmers whom you represent. And I want your help and cooperation in trying to make of Illinois farming something more than farm work. There was nothing in my farm work to be especially proud of, except, possibly, my willingness to work. I did the work as my father and my father's father had done it. I worked hard but I worked ignorantly.

I well remember that I worked just as hard and took as much pains to get a crop of 15 bushels of wheat from *our* land as Charles Cass, a neighbor only three miles from us, did to raise 30 bushels on some of his land. Why was the difference? We said he had better land. But why his land was better I did not know. I did not know that plant growth is absolutely dependent upon the presence of certain elements of plant food in the soil. I did not know

that when the available supply of any one of these essential elements falls short then the crop must also inevitably fall short, no matter how hard I worked. As a matter of fact I knew no more about the land than Lot knew four thousand years ago when he parted from Abraham and chose to dwell "in the land of the plain of Jordan." Certainly I knew how to do farm work; I was well trained in most all farm operations, from digging out grubs and stumps in the timber land, or breaking the prairie sod with a four horse team, to building a barn or granary, or stacking wheat or oats to shed rain.

Nitrogen! phosphorus! potassium! available fertility! nitrifying and nitrogen-gathering bacteria! fixation of carbon! soil acidity!—Have those words anything to do with farming? If so, I did not know it. It seems to me that all I knew about farming was to work myself and to "rest" the land by rotating crops. And we rotated crops just as an Illinois farmer told me last summer he does. I asked him what crop he usually grew after wheat. He said, "That depends. If we get a fairly good crop of wheat, we usually grow wheat again." So did we. We grew wheat till the land grew tired, then we gave it a "rest" by growing corn or oats or timothy. Why clover would not grow we did not know.

But this I do know, that when my good father started me to an agricultural college he said, "Try to learn something about the soil;" and I know that when I began to study chemistry I said to my teacher, "Let me learn to analyze soils," and I fail to remember any more bitter disappointment than I had then when the professor said, "That is a hard thing to do; for to analyze the soil is one of the most difficult chemical analyses to make, and, furthermore, soil analysis doesn't seem to mean very much."

Nevertheless, I have learned to analyze soils, and to me soil analysis *means very much*.

Again I beg your pardon for these personal remarks.

But let me ask you, why are the people of Europe buying 1,000,000 tons of American rock phosphate each year? Are they ignorant and mistaken regarding its value; and is all the wisdom pertaining to agricultural science and practice locked up in the minds of the good, hardworking, honest men who run many of the farms of Illinois for \$5 an acre cash rent or for one-half of all they can squeeze out of the soil?

Gentlemen of the Illinois State Farmers' Institute, my knowledge is small and my data few, but my opinion is that every ton of bone meal and every ton of rock phosphate annually produced in the United States could be used with marked profit upon the soils

of Illinois, Indiana, and Ohio. I said with profit; but I also say, were there no marked profit in it, we should put back upon the soil at least as much phosphorus as we take off,—Yes we should put back as much as we have taken off during the past half century or more. But I believe that the purchase and intelligent use of phosphorus on many Illinois soils will ultimately pay a higher interest on the investment than the purchase of Illinois soils themselves, at present prices. When you buy land you do not expect it to pay back the principal the first year, neither should you expect it from heavy applications of plant food of which perhaps 90 per cent. remains in the soil to benefit succeeding crops.

I do not advise farmers to rush into the purchase of phosphorus or other plant food on a large scale, but I do advise every land owner to lay off two uniform strips of land, about one acre each, through every important field, to take the exact yields of those two strips for a year or two, then to apply to one of these strips from year to year the treatment which from all the information obtainable he thinks ought to be given to it to insure the permanent maintenance or increase of its productive capacity; and then, if he finds it is profitable, or even if he can barely afford to do it, I advise him to apply this treatment to his whole farm, excepting only the untreated acre, which should always be reserved as a check to show what the soil would do without such treatment.

The Illinois State Farmers' Institute is the organization which first asked for an appropriation for the investigation of the soils of the State, and I trust the future generations will give you honor for it.

I now assume that the members of the Illinois State Farmers' Institute will be the leaders in applying and extending the knowledge which may be derived from these investigations, as rapidly as results may be secured and verified which shall be found practical for preserving the productive capacity of Illinois soils.

As I said in the beginning :

If the greatest study of mankind is Man, the next greatest study is the soil; for, upon the soil, depends the preservation of Man.

If it is true that American agriculture is the fundamental support of the American Nation, it is equally true that soil fertility is the absolute support of American Agriculture.

If he who makes two blades of grass grow where but one grew before is a public benefactor, then he who reduces the fertility of the soil so that but one ear of corn grows where two grew before is a public curse.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

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DIRECTIONS FOR THE BREEDING OF CORN.

BY LOUIE H. SMITH, CHIEF ASSISTANT IN PLANT BREEDING.

The practicability of the improvement of corn by systematic selection and breeding has now been definitely established, and on account of a general awakening to the importance of this matter, numerous inquiries are coming to this Experiment Station regarding the practical methods which can be followed by any grower who desires to improve his corn.

It is in view of meeting these inquiries with a statement as simple and concise as possible that this circular is prepared.

Corn improvement should embrace both quantity and quality. But, because of the great importance of increased yield per acre, all selection looking toward improvement should be first based upon yield, this to be followed so far as practicable, with efforts which aim toward higher standards of quality. It is with these ideas that the following methods for corn breeding are arranged.

PHYSICAL SELECTION OF SEED CORN.

The most perfect ears obtainable of the variety of corn which it is desired to breed should be selected. As a rule, these seed ears should be obtained from some reliable seed corn breeder in preference to starting with unknown and unimproved corn.

In making the selection for desirable ears, as judged from the physical characteristics, the larger the number of ears ex-

amined the better can be the selection. If the breeder wishes to improve the quality (chemical composition) of the grain, as well as the yield and type of his corn, it is recommended that he choose at least 200 ears of the desired physical type to be further examined as to quality.

CHEMICAL SELECTION BY MECHANICAL EXAMINATION.

The following table fairly illustrates the results obtained by the use of the method of mechanical examination in the selection of high protein seed ears.

RESULTS OF SELECTION FOR PROTEIN IN CORN BY METHOD OF MECHANICAL EXAMINATION.

Selected by	Total number ears examined	Ears Selected As High in Protein.		Ears Rejected as Not High in Protein	
		Number of ears.	Ave. % protein.	Number of ears.	Ave. % protein
Ill. Exp. Station (1902) .	200	42	12.14	42*	10.67
Ralph Allen (1902)	165	15	13.56	150	12.10
Ralph Allen (1903)	225	15	13.15	210	11.51
A. L. Woodhams	187	36	11.59	151	10.29
Hunt Bros	200	40	10.94	160	10.88
William Berg	200	25	11.59	175	11.29
H. A. Winter	134	26	11.37	108	10.78
W. G. Griffith	(?)	24	10.64	(?)	9.94
Ohio Exp. Station	4 bushels	14	11.71	(?)	9.70

*Selected for low protein from same lot of 200 ears.

The success of this method in the hands of several practical farmers is demonstrated. We notice that in every case there was a gain made in average protein content of the selected ears, and in some of these cases the gains were very decided.

METHOD OF MECHANICAL EXAMINATION.

The method of making a chemical selection of ears of seed corn by a simple mechanical examination of the kernels is based upon the fact that the kernel of corn is not homogenous in structure, but consists of several distinct and readily observable parts of markedly different chemical composition. For a complete detailed study of "the structure of the corn kernel and the composition of its different parts," see Bulletin No. 87.

For our particular purpose of judging from the structure of the kernel as to its composition, we need consider but three principal parts, namely:

1. The darker colored and rather horny layer lying next to the hull, principally in the edges and toward the tip end of the kernel. This part is fairly rich in protein and contains from one-half to two-thirds of all the protein of the kernel.

2. The white, starchy-appearing part occupying the crown end of the kernel and usually also immediately surrounding, or partially surrounding, the germ. This part is poor in both protein and oil, consisting mainly of starch.

3. The germ itself, which occupies the central part of the kernel toward the tip end. This is very rich in oil. More than four-fifths of the entire oil of the kernel resides in the germ. It is also rich in protein, containing nearly one-fifth of all the protein in the kernel, although the germ itself constitutes only about one-tenth of the weight of the kernel.

In selecting seed corn by mechanical examination for improvement in composition, we remove from the ear a few average kernels. Cut these kernels into cross sections and examine these sections as they are cut, usually simply with the naked eye, selecting for seed those ears whose kernels show the qualities desired.

SAMPLES FOR ANALYSIS.

In order that the breeder may know what he has accomplished in his work of mechanical selection, the Experiment Station offers to analyze for any Illinois farmer who wishes to improve the quality of his corn by breeding according to these directions and who agrees to make the best selection of seed possible, two composite samples representing each of the two lots of ears; that is, the selected lot and the rejected lot.

One composite sample should be made by taking 10 average kernels from each of the selected ears (96 ears preferred), and another sample should be made by taking 10 average kernels from each of the rejected ears (100 ears or more). Each of these two samples should be put in a separate sack, properly labeled, and sent to the Plant Breeding Laboratory, Agricultural Experiment Station, Urbana, Ill.

Of course, if the breeder desires to breed for physical type and increased yield only, then no chemical analysis is needed, and all that is necessary to begin work is to select the 96 most nearly perfect ears obtainable for the breeding plot.

SIZE OF BREEDING PLOT.

The best number of ears to use in a breeding plot is as yet an unsettled question. There are several conflicting factors entering into the consideration. On the one hand, the smaller the number of ears taken, the choicer can be the selection of the seed planted; while on the other hand, the larger the number of breeding rows to choose from, the better can be the selection of seed for the next crop. Then again, there is undoubtedly some danger of evil effects from too close in-breeding, by the use of too small a number of ears.

From our present knowledge we believe, however, that 96 ears is a safe number to use, so far as in-breeding is concerned, and this is the number that we suggest in these directions, it being understood that alternate rows are to be detasseled and all seed corn selected from detasseled rows.

PLANT BY THE ROW SYSTEM.

The 96 selected seed ears are planted in 96 separate rows. These rows should be at least 100 hills long, but they may well be 40 rods long, as the amount of seed will usually permit this.

It is recommended that these 96 seed ears be numbered* from 1 to 48 and from 51 to 98, the numbers 49 and 50 being omitted; also that ears 1 to 48 be planted in one-half of the plot and ears 51 to 98 be planted in the other half, preferably end-to-end with the first half, leaving one hill unplanted to mark the line between the two halves, also leaving one row unplanted to mark the line between rows 24 and 25 and between rows 74 and 75; that is, between quarters.

In this way row 51 (planted with seed from ear 51) is a continuation of row 1 (planted with seed from ear 1) and the two rows may well extend 80 rods, across a 40-acre field. The breeding plot can be planted with a corn planter, although it will require some time and patience, and if the planter is an edgedrop it will be necessary to put a suitable cone or inverted funnel in each seed box so as to keep the small amount of corn to the outside. Place the shelled corn from ear No. 1 in one box and from ear No. 2 in the other; drive to the middle line of the plot, thus planting rows 1 and 2; clean out the boxes;

*These numbers would be 101 to 148 and 151 to 198 the first year, 201 to 248 and 251 to 298 the second year, etc., etc. (See under REGISTER NUMBER, page 12.)

move forward one hill; put in the corn from ears 51 and 52; use the foot trip till the corn begins to drop; then drive on and plant rows 51 and 52. Turn at the end; clean out the seed boxes; put in ears 53 and 54; plant back to the middle; clean out, put in ears 3 and 4, and then plant on back to the beginning line, thus continuing until the breeding plot is all planted. The planting may then be continued for the commercial field, using the same variety of corn, which should be of similar breeding but not too closely related, finishing, perhaps, with the multiplying plot on the opposite side of the field from the breeding plot.

Each one of the breeding plot rows should be numbered to correspond with the "register number" of the ear from which it is planted, as will be explained under the heading of "Pedigree Register."

The breeding plot should be well protected from foreign pollen, by being planted as far away as possible from other varieties of corn.

DETASSELING.

From the data which we have secured and are securing upon the subject, we now strongly recommend that every alternate row of corn in the breeding plot be completely detasseled before the pollen matures and that all of the seed corn to be taken from the plot be selected from these 48 detasseled rows. This method absolutely prohibits self-pollination or close-pollination of the future seed. By self-pollination is meant the transfer of pollen from the male flower (tassel) of a given plant to the female flower (silk) of the same plant; and by close-pollination is meant the transfer of pollen from the male flower of one plant to the female flower of another plant in the same row, both of which grew from kernels from the same seed ear. It is recommended that no plants in any of the rows which appear imperfect, dwarfed, immature, barren, or otherwise undesirable, should be allowed to mature pollen. Occasionally an entire row should be detasseled because of the general inferiority of the row as a whole. Detasseling is accomplished by going over the rows as many times as may be necessary and carefully pulling out the tassels as they appear. Indeed, great care should be exercised in this part of the work in order not to

injure the plants and thereby lower the yields. The tassels should not be cut off, as this produces an external injury and at the same time the stalk is often deprived of several undeveloped leaves. But the tassel should be allowed to develop far enough so that it can be separated alone at the top joint by a careful pull. It is now fully determined that the detasseling of the breeding rows is necessary. This insures cross pollination and markedly increases the yield of succeeding crops.

SELECTION OF FIELD ROWS AND SEED EARS.

As the crop matures, the corn from each of the detasseled breeding rows is now harvested. First, all of the ears on the row which appear to be good ears and which are borne on good plants, in a good position, and with good ear shanks and husks, are harvested, placed in a bag, with the number of the row, and finally weighed, together with the remainder of the crop from the same row. No seed ears should be taken within two or three rods of the inside ends of the rows. The total weight of ear corn which every detasseled row yields should be determined and recorded, for the yield is the primary factor in determining the rows from which all of the ears for the next year's seed selection must be taken. Each lot of ears from each of the detasseled rows, and finally each single ear of the 96 seed ears ultimately selected is kept labeled with the number of the row in which it grew and finally with its own ear number also, and permanent records are made of the number and the description of the ear, the performance record of the row, etc., so that as the breeding is continued an absolute pedigree is established, on the female side, for every ear of corn which may be produced from this seed so long as the records are made and preserved. We also know absolutely that we have good breeding on the male side, although the exact individual pedigree of the males cannot be known and recorded.

PLANTING FOR CROSS POLLINATION.

In order to insure cross breeding to the greatest possible extent the plan given in Table 1 should be adopted.

Table 1. Plan for Planting the Breeding Plot to avoid In-Breeding. The numbers given in the "Guides" designate the field rows from which the seed ears are taken. (All even-numbered rows are detasseled.)

Field row No.	Guide system for even years.	Guide system for odd years.	Model example for an even year.	Field row No.	Guide system for even years.	Guide system for odd years.	Model example for an even year.
1.	76.	78.	76.	51.	2.	4.	4.
2.	2.	2.	4.	52.	52.	52.	52.
3.	80.	82.	84.	53.	6.	8.	10.
4.	6.	6.	10.	54.	56.	56.	58.
5.	84.	86.	90.	55.	10.	12.	16.
6.	10.	10.	16.	56.	60.	60.	66.
7.	78.	76.	80.	57.	4.	2.	8.
8.	4.	4.	8.	58.	54.	54.	56.
9.	82.	80.	86.	59.	8.	6.	14.
10.	8.	8.	14.	60.	58.	58.	60.
11.	86.	84.	92.	61.	12.	10.	20.
12.	12.	12.	20.	62.	62.	62.	68.
13.	78.	76.	80.	63.	4.	2.	8.
14.	2.	2.	4.	64.	52.	52.	52.
15.	82.	80.	86.	65.	8.	6.	14.
16.	6.	6.	10.	66.	56.	56.	58.
17.	86.	84.	92.	67.	12.	10.	20.
18.	10.	10.	16.	68.	60.	60.	66.
19.	76.	78.	76.	69.	2.	4.	4.
20.	4.	4.	8.	70.	54.	54.	56.
21.	80.	82.	84.	71.	6.	8.	10.
22.	8.	8.	14.	72.	58.	58.	60.
23.	84.	86.	90.	73.	10.	12.	16.
24.	12.	12.	20.	74.	62.	62.	68.
25.	52.	54.	52.	75.	26.	28.	30.
26.	26.	26.	30.	76.	76.	76.	76.
27.	56.	58.	58.	77.	30.	32.	36.
28.	30.	30.	36.	78.	80.	80.	84.
29.	60.	62.	66.	79.	34.	36.	42.
30.	34.	34.	42.	80.	84.	84.	90.
31.	54.	52.	56.	81.	28.	26.	34.
32.	28.	28.	34.	82.	78.	78.	80.
33.	58.	56.	60.	83.	32.	30.	38.
34.	32.	32.	38.	84.	82.	82.	86.
35.	62.	60.	68.	85.	36.	34.	46.
36.	36.	36.	46.	86.	86.	86.	92.
37.	54.	52.	56.	87.	28.	26.	34.
38.	26.	26.	30.	88.	76.	76.	76.
39.	58.	56.	60.	89.	32.	30.	38.
40.	30.	30.	36.	90.	80.	80.	84.
41.	62.	60.	68.	91.	36.	34.	46.
42.	34.	34.	42.	92.	84.	84.	90.
43.	52.	54.	52.	93.	26.	28.	30.
44.	28.	28.	34.	94.	78.	78.	80.
45.	56.	58.	58.	95.	30.	32.	36.
46.	32.	32.	38.	96.	82.	82.	86.
47.	60.	62.	66.	97.	34.	36.	42.
48.	36.	36.	46.	98.	86.	86.	92.

In this plan the breeding plot is considered by quarters. Each quarter contains 24 rows and each row is planted with corn from a separate seed ear. All even-numbered rows are detasseled and seed for the next year's breeding plot is taken from the six best yielding detasseled rows in each quarter, four ears being taken from each selected row, making 96 ears in all.

For convenience we use the term "sire seed," or "sire ears," to designate the ears which are to be planted in odd-numbered rows to produce tassels (the male flowers) and to furnish pollen; and we use the term "dam seed" or "dam ears" to designate the ears to be planted in the even-numbered rows to produce future seed ears. Of the four seed ears taken from each selected field row, two are used for sire seed and two for dam seed.

In the column headed "Guide system for even years" is given a key or guide, by which to work out the actual plan for planting in all even-numbered years, and under the heading "Model example for an even year" is given an actual plan which has been worked out, using four seed ears from six selected rows from each quarter of the breeding plot.

In the guide system, for the sake of simplicity, we use four seed ears from each of the first six even-numbered rows in each quarter, a selection which would probably never occur in actual practice.

It will be observed that the dam seed ears for each quarter are ears which grew in the same quarter, while the sire seed is always brought from another quarter. For the first quarter (rows 1 to 24), sire ears are brought from the fourth quarter. For the second quarter, sire seed is brought from the third. In each of these cases sire seed is carried diagonally across the breeding plot. For the third quarter sire seed is brought from the first quarter, and for the fourth, from the second, the sire seed being carried lengthwise of the breeding plot in these cases.

It will also be observed that there is a definite order of planting for "even years" and another definite order for "odd years." Thus, in the first quarter, the even-numbered rows are planted in ascending order with dam seed selected from rows numbered: 2, 6, 10: 4, 8, 12=2, 6, 10: 4, 8, 12.

The alternating even numbers are repeated in sets of three and six. The odd-numbered rows are planted with sire seed selected from rows numbered: 76, 80, 84: 78, 82, 86 = 78, 82, 86: 76, 80, 84.

This is the same order as for the dams except that the two sets of three are reversed in the second set of six. The only change required for odd-numbered years is to transpose the two sets of six in planting the sire seed. Exactly the same system is used in each quarter of the breeding plot.

ARRANGING SEED EARS FOR PLANTING.

By referring to the "Model example for an even year" it will be seen that it becomes an easy matter to follow the "Guide system" in arranging seed ears for planting. Suppose, for example, that in 1905 the best six rows in the first quarter of the breeding plot are 4, 8, 10, 14, 16, 20. Then for the dam seed for planting the first quarter in 1906 these numbers, in ascending order, are to be substituted for the numbers 2, 4, 6, 8, 10, 12, which are given in the "Guide system."

Thus: For 2, substitute 4; for 4, substitute 8; for 6, substitute 10; for 8, substitute 14; for 10, substitute 16; for 12, substitute 20.

Arranging these for planting the field rows, we have:

ROW NO.	GUIDE SYSTEM.	ACTUAL PLAN.
2	2	4
4	6	8
6	10	10
8	4	14
10	8	16
12	12	20
14	2	4
16	6	8
18	10	10
20	4	14
22	8	16
24	12	20

If the best six rows in the fourth quarter of the 1905 breeding plot are 76, 80, 84, 86, 90, 92, then for the sire seed for planting the first quarter in 1906 these numbers are to be substituted in regular order for the numbers 76, 78, 80, 82, 84, 86, which are given in the "Guide system." Arranging these by threes as indicated in the "Guide system" we have the order

for planting the odd-numbered rows in the first quarter: 76, 84, 90: 80, 86, 92=80, 86, 92: 76, 84, 90.

Thus we have both the dam and sire seed ears for the first quarter, arranged exactly as shown under the heading "Model example" in Table 1. The seed ears are arranged for each quarter of the breeding plot in a similar manner by following the "Guide system" and substituting in regular ascending order the actual numbers of the best yielding rows for the numbers given in the "Guide system" in Table 1.

It will be seen that with this selection of best rows, as given in this "Model example," we would take the four best seed ears from row No. 4 (1905) and plant two as dam ears in rows 2 and 14 and the other two as sire ears in rows 51 and 69 (1906); we would take the four best seed ears from row No. 84 (1905) and plant two as dam ears in rows 78 and 90 and the other two as sire ears in rows 3 and 21 (1906).

In arranging seed ears selected from the 1906 breeding plot for planting the 1907 breeding plot, we are to follow the "Guide system" for odd-numbered years, again returning to the system for even-numbered years, for 1908.

MULTIPLYING PLOT.

Seed for a multiplying plot of ten acres or more should be taken only from the selected rows of the breeding plot, and may include all good seed corn which is not required for the breeding plot. This seed may be mixed together and planted on the multiplying plot. The corn grown in the multiplying plot should be carefully protected from foreign pollen and all inferior stalks should be detasseled. The exact yield of the multiplying plot should be determined and registered.

COMMERCIAL FIELD.

The seed for the commercial field should be only the best obtainable seed corn from the multiplying plot. The exact yield of the commercial field should be determined and registered. From the commercial field the finest ears may be selected and sold to the trade as pedigreed seed corn.

PEDIGREE REGISTER.

The Experiment Station has adopted a form for registering the numbers and descriptions of all the seed ears used in corn breeding and also for recording their performance records.

Breeder.....

OF EARS PLANTED AND ROWS HARVESTED

Distance between hills.....

IN SEASON OF

Number of hills in row.....

[illegible]

In this form there is provided space only for those measurements and data which now seem to be essential, as well as of general practicability in breeding up valuable strains of corn. There are some extra columns which may be used for any special points upon which any breeder may be working.

DESCRIPTION OF INDIVIDUAL EARS.

REGISTER NUMBER.—As soon as any ear is selected to be planted in a breeding plot, it is given a "Register Number," which must, of course, represent that particular ear only and for all time. By using a certain system of numbering we are not only able to accomplish this purpose, but can show at the same time the year of its breeding or the number of its generation. This we do by starting the first year in the 100 series, numbering the ears to be planted in succession from 101 to 148 and 151 to 198, and the second year starting the 200 series, running from 201 to 248 and 251 to 298, and so on, starting each succeeding year with a higher hundred.

DAM NUMBER.—The "Dam Number" is the "Register Number" of the parent ear and is useful in tracing the pedigree record from year to year back to the source.

ANNUAL EAR NUMBER.—In order to designate the 200 or more ears selected from the field, each one is given an "Annual Ear Number," which runs in a series from 1 up to 200 or more. and the numbers should follow the order of the breeding rows. This number is only temporary, to serve while working on the corn for the final selection of seed ears, and when the seed ears are selected to be planted, each is given a permanent "Register Number," as explained under that heading.

LENGTH OF EAR.—This is the measurement in inches of the total length from butt to tip.

TIP CIRCUMFERENCE OF EAR.—This is the measurement in inches at two inches from the tip end of the ear.

BUTT CIRCUMFERENCE OF EAR.—This is the measurement in inches two inches from the butt end of the ear.

NUMBER OF ROWS OF KERNELS.—This is self-explanatory.

NUMBER OF KERNELS IN ROW.—This is the average number of kernels in the row from tip to butt.

WEIGHT OF EAR.—This is taken in ounces after it has become thoroughly air-dried.

WEIGHT OF COB.—This is taken in ounces after it has become thoroughly air-dried.

TIP CIRCUMFERENCE OF COB.—This is the measurement in inches, two inches from the tip end.

BUTT CIRCUMFERENCE OF COB.—This is the measurement in inches, two inches from the butt end.

PERCENT PROTEIN IN GRAIN.—The Experiment Station is breeding some varieties in which every individual seed ear is subjected to an exact chemical analysis for the protein content of the grain, and this column is provided for the result of such tests.

PERCENT OIL IN GRAIN.—The Experiment Station is breeding some varieties in which a chemical oil test is made of each individual seed ear, and this column provides for the records of such data.

PERFORMANCE RECORD OF FIELD ROWS.

PLANTED IN FIELD ROW NUMBER.—The field row or breeding row numbers should, for the sake of convenience, correspond with the register numbers of the ears planted; for example, ear "Register No." 101 should be planted in "Field Row No." 1.

CORN POUNDS PER ROW.—The total yield of ear corn of every breeding row of the plot should be recorded in pounds.

CORN BUSHELS PER ACRE.—This is computed from "corn pounds per row," and from the "distance between hills" and "number of hills in row," as recorded in the upper right hand corner of the sheet. The full number of hills per row should always be used in this computation unless otherwise noted. The number of pounds per bushel should be estimated as fairly as possible, depending upon the condition of the crop at the time of harvest. (Commonly 75 or 80 pounds are used.)

TOTAL NUMBER OF EARS IN ROW.—This includes nubbins, as well as good ears. The total weight of ears and the total number gives a general idea as to the average size. Some breeders also desire to record the number of good seed ears produced. Such records can be placed in the blank columns.

PERCENT OF PROTEIN IN GRAIN.—This column is provided for those varieties in which an exact chemical control is being

kept of the parent ears and their offspring, and for averages when seed ears are selected by mechanical examination.

PERCENT OF OIL IN GRAIN.—The same note applies here as above.

On the same sheet with the complete year's record of the breeding plot appear the records of the multiplying plot for the same year, and for the next year following, and also the records of the commercial field for the same year and for the next two years. If the record sheet is for the breeding plot for 1904 it is important to finally record on the same sheet the record of the multiplying plot for 1905, and of the commercial field for 1906, and for convenience and comparison it is well to record on the same sheet the yield of the multiplying plot for 1904, and the yields of the commercial field for 1904 and 1905. If a breeding plot were started in 1904, the breeder could have both a breeding plot and a multiplying plot in 1905, and a breeding plot, multiplying plot, and commercial field in 1906; and from the 1906 crop on the commercial field he could sell seed corn with a registered pedigree of three years, one year in the breeding plot, one year in the multiplying plot, and one year in the commercial field. In 1910 he could sell seed corn from his commercial field with a registered pedigree of seven years—five years in the breeding plot (1904, 1905, 1906, 1907, and 1908), one year in the multiplying plot (1909), and one year in the commercial field (1910).

At the bottom of the corn register sheet is a space under "Remarks," in which any irregularities concerning the data of the sheet may be explained; or there can be placed here any short notes that it may be desirable to record in regard to the soil of the plot, the weather, or any other conditions affecting growth.

These corn register sheets may be secured upon application to the Experiment Station by any Illinois farmer who wishes to start a breeding plot.

THE EXPERIMENT STATION HAS NO SEED CORN FOR SALE.

On account of the numerous calls that are constantly being received by us for seed corn, it is thought well to explain here that the Experiment Station has no seed of any kind for dis-

tribution. It is the particular province of the Experiment Station to investigate and to demonstrate principles. Others make the commercial application of these principles whenever they are proved to be of commercial importance.

For the sake of the definite knowledge to be gained, investigations are often carried on to determine what we should avoid doing in practical agriculture, as well as to discover what we should do for improving agricultural conditions or practices. The station has demonstrated the possibility, through selection and breeding, of improving corn both as to yield and as to quality. Marked changes have been produced in the composition of corn. We recognize the fact, however, that there may be a limit beyond which these changes in composition cannot be carried without interfering with the physiological functions of the seed and plant to the extent of impairing the yield. Therefore these experiments are being carried on still farther to determine if possible where the danger limits lie, in order that we may be able to point out such limits to practical corn breeders who follow along in these lines of corn improvement.

For our first experiments in corn breeding, which began some eight years ago, we selected a variety of corn of medium size and of safe maturity for this latitude with which to work out methods, and to ascertain the possibilities of corn improvement. This variety was well adapted to our purpose, but it was not one of our largest or highest yielding varieties of corn. This preliminary work was necessarily carried on on a small scale and the original experiments are still being continued on about the same scale. While we have definitely determined, for example, that the protein of corn can be increased by breeding; we now wish to determine whether this might be carried to such an extent as to result in impaired constitution or vigor of growth or reduced yield. If there is such a danger point, then the Experiment Station should discover the fact before it is actually reached by the practical corn breeders.

As soon as we had demonstrated that the improvement of corn by breeding was both possible and practicable, a considerable number of the most successful seed corn producers in Illinois adopted our methods of corn improvement, and for sev-

eral years they have been systematically breeding corn on a large scale. Thus it happens that while the methods and principles have been worked out and demonstrated by the Experiment Station on plots of less than one acre in size and with corn of medium size and yield, the commercial seed corn breeders are now applying these principles to hundreds or even to thousands of acres, and while they began some four years after the first experiments were undertaken by us, they began with all of the different leading varieties of corn grown in the state, and, moreover, they are breeding different varieties of corn especially adapted to different sections of the state.

Furthermore, several members of the Illinois Seed Corn Breeders' Association, recognizing the importance of producing corn especially adapted to special purposes, have taken up the work of improving the quality of their varieties along different lines, following the methods established by the Experiment Station. Thus they are breeding first for improvement in yield, and, second, for improvement in composition. Some of them are breeding to increase the protein content, and others to increase the oil content in their corn, while some varieties or strains are being bred for a combination of high protein and high oil.

There is another point which has a bearing on this work, namely, we selected a variety of corn of average composition; and from this we began breeding in several different directions, one for high protein and one for low protein, another for high oil and still another for low oil. This variety of corn was not especially high in protein when we began with it, not so high, in fact, as some other varieties which we were growing at the time and which are now being bred for high protein by some of the Illinois seed corn breeders.

For information concerning Illinois Seed Corn Breeders and the varieties of corn they are breeding, the reader is referred to their secretary, Mr. John R. Clisby, Arcola, Illinois.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

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CIRCULAR NO. 75.

FEEDING DAIRY COWS.

By Wilber J. Fraser, Chief in Dairy Husbandry.

1. Secure the rough fodders in the best possible condition and use them liberally, as they are much cheaper than concentrates.
2. Feed concentrates in proportion to the milk flow.
3. Study and supply the individual needs of each cow.

Before man had control over animals and they became domesticated, there were no highly specialized forms, and when they roved wild on the prairies or in the forests, the problem of the particular kind and character of their food supply was not an important one for they were not expected to draw loads of several tons weight, or to produce the abnormal yields of milk that are given by the highly developed dairy cows of today. However, after man domesticated animals and began to develop breeds suited to special purposes, as draft, speed, beef, or milk, the question of their food supply became an all important one, for in order to secure the best results their food must be adapted to their special needs.

One fact of great importance, and which must not be lost sight of in economical feeding, is, that the amount, kind, and character of the food an animal requires depends entirely upon the use to which that animal is going to put the food. A cheap team may be kept through

an idle time on a kind of feed that would not be at all suited to the needs of a race-horse during the training season, or of a valuable cow yielding 100 pounds of milk a day during an official test.

In order that a cow may produce the greatest yield of which she is capable she must be given the right kinds of feed and the correct amount of each. There is little use in paying high prices and establishing a good dairy herd unless careful attention is to be given to the amount and character of the feed, for however well bred and efficient the individuals they cannot give in their product what they do not receive in their food.

The nutrients contained in all feeding stuffs, as well as in animal bodies and in milk, may be divided into five classes as follows:

Water.

Ash, (mineral compounds.)

Protein, (nitrogen compounds.)

Carbohydrates, (starches, sugar, etc.)

Fats, (or oils.)

While an ample supply of pure water is one of the first requisites of good stock feeding, it is usually supplied in abundance at comparatively little cost and will not be considered further in this discussion.

Ash or mineral matter is present in all feeding stuffs in sufficient quantities so that an animal properly nourished with the other constituents is sure to receive enough mineral matter; we will, therefore, pass this group of substances also.

PROTEIN.

Protein is the name applied to the constituents of feeds which contain nitrogen, and feeding stuffs which are rich in this element are frequently called nitrogenous feeds. Among these are: oil meal, cotton-seed meal, gluten meal, and the legumes, as cowpeas, alfalfa, and clover. The white of an egg, the lean part of meat, and the casein of milk are all good examples of protein.

The principal uses of protein in the body of the cow are to build muscles, replace their waste, and form casein in milk. There are two reasons why special attention should be given to the amount of protein contained in the different feeds: first, because it is usually deficient in feeds for dairy cows; second, because no other nutriment answers the same purpose.

CARBOHYDRATES.

Carbohydrates is the name applied to the carbonaceous group of

substances such as starch, sugar, and the woody parts of plants known as crude fiber. This group forms the larger part of the food consumed by animals, as we shall see later. Carbohydrates furnish energy to perform the body functions and for the muscular activity. The heat of the body is the result of energy expended. It takes a large amount of energy to build up a product like milk. If carbohydrates are fed in excess of the demands for energy, fat may be stored up in the body. In the case of the dairy cow, carbohydrates, besides supplying the above requirements, furnish the constituents for forming milk sugar and fat in milk.

FAT.

Every one is familiar with fat in its different forms; as tallow in the steer, lard in the hog, and butter fat in milk. In corn there is about 4.3 percent of fat, or oil, and in flaxseed a much larger proportion, while in most of the rough fodders there is comparatively little. Fat in the food nourishes the body in exactly the same way as do carbohydrates: namely, furnishes energy and forms fat. The chief difference between fat and carbohydrates is that the former is a more concentrated form of food, one pound being equal to 2.4 pounds of carbohydrates. It should be remembered that fat and carbohydrates are interchangeable, that is, whichever one is in excess may take the place of the other, but it must also be borne in mind that however great the excess of carbohydrates and fat in the ration, no more muscle can be formed in the body, or casein produced in the milk than there is protein in the food supplied. In other words, where protein is in excess it can take the place of carbohydrates and fat, but no amount of carbohydrates and fat can take the place of protein in the least degree.

DIGESTIBLE NUTRIENTS.

The digestibility of the different constituents of feeds is of great importance, as only that portion of feeding stuffs which passes into solution during the process of digestion and is absorbed into the blood is of value in nourishing the animal. This portion of the various feeds is known as the digestible nutrients.

The difference between the total nutrients and the total digestible nutrients is marked: for example, by referring to feeding tables we find that in 100 pounds of clover hay there are 12.3 pounds of protein, but of this only 6.8 pounds are digestible and can be used to nourish the animal. The digestible nutrients are, therefore, the only ones considered in making up rations.

TABLE 1. DIGESTIBLE NUTRIENTS REQUIRED PER DAY FOR A 1000-
POUND COW FOR MAINTENANCE AND FOLLOWING YIELDS.

	Protein, lb.	Carbohy- drates, lb.	Fat, lb.	Nutritive ratio.
For maintenance	.7	.7	.1	1: 10.3
10 lb. milk 3% fat	1.10	8.81	.24	1: 8.3
10 " " 4% "	1.17	9.16	.26	1: 8.4
10 " " 5% "	1.24	9.51	.29	1: 8.2
20 lb. milk 3% fat	1.49	10.62	.37	1: 7.7
20 " " 4% "	1.63	11.32	.42	1: 7.5
20 " " 5% "	1.77	12.02	.47	1: 7.4
30 lb. milk 3% fat	1.89	12.43	.51	1: 7.2
30 " " 4% "	2.10	13.48	.58	1: 7.1
30 " " 5% "	2.31	14.53	.66	1: 7.0
40 lb. milk 3% fat	2.29	14.24	.64	1: 6.9
40 " " 4% "	2.57	15.64	.74	1: 6.8
40 " " 5% "	2.85	17.04	.84	1: 6.7
50 lb. milk 3% fat	2.68	16.05	.78	1: 6.7
50 " " 4% "	3.03	17.80	.90	1: 6.6
50 " " 5% "	3.38	19.55	1.03	1: 6.5
60 lb. milk 3% fat	3.08	17.86	.92	1: 6.5
60 " " 4% "	3.50	19.96	1.07	1: 6.4
60 " " 5% "	3.92	22.06	1.22	1: 6.3

Much careful study and investigation has been devoted to the question of determining the amounts of digestible protein, carbohydrates, and fat needed for cows of different weights and varying yields. To Professor T. L. Haecker belongs the credit of securing the data from which Table 1 has been computed.

In all animals there is a constant breaking down of the body tissues caused by wear, and there is energy expended in keeping up the vital processes and in maintaining the body temperature. The food used to rebuild worn-out tissues and to furnish heat and energy when the animal is at rest is called the food of maintenance. If a 1000-pound cow is producing 30 pounds of 4 percent milk she will require digestible nutrients about as follows:

	Protein, lb.	Carbohy- drates, lb.	Fat, lb.
For maintenance	.7	7.	.1
For producing 30 lb. of 4% milk	1.40	6.48	.48
Total nutrients required for maintenance and milk	2.10	13.48	.58

A cow of the same weight producing 40 pounds of 4 percent milk will require a ration containing 2.57 pounds protein, 15.64 pounds carbohydrates and .74 of a pound fat. If her yield were 50 pounds of 4 percent milk her ration should contain 3.03 pounds protein, 17.80 pounds carbohydrates and .90 of a pound fat.

In feeding dairy cows, the fact that they should be fed according to their milk production, is frequently overlooked. A cow capable of producing 60 pounds of 4 percent milk a day must be fed a much larger amount of digestible nutrients, if she is to produce her greatest yield, than a cow giving only 10 pounds of milk testing 3 percent. This point should be strongly emphasized, for a cow cannot give in her product what she does not receive in her food. By referring to Table 1 the nutrients required for any yield of milk may be easily determined. If the cow weighs more or less than 1000 pounds a proportional increase or decrease in the food for maintenance should be made.

From the weight of a cow and the amount of milk she will produce on liberal feeding the required nutrients may be determined. The next step is to select such feeds as will best supply these nutrients. We will take, for example, a 1000-pound cow producing 30 pounds of 4 percent milk, and by referring to Table 1, find that she requires 2.1 pounds protein, 13.48 pounds carbohydrates and .58 of a pound fat.

If one wishes to feed clover hay and corn and cob meal he can make up a trial ration by taking 15 pounds of clover hay and 8 pounds of corn and cob meal. The nutritive value of each of these feeds can then be found from the table on page 15, which gives the amount of digestible nutrients in 100 pounds of the different feeds. We find that 100 pounds of clover hay contain 6.8 pounds protein, 35.8 pounds carbohydrates and 1.7 pounds fat. Dividing each of these amounts by 100 we have the digestible nutrients in one pound; multiplying by 15 we have the digestible nutrients in 15 pounds, which are 1.02 pounds protein, 5.37 pounds carbohydrates and .25 of a pound fat. In the same manner are found the protein, carbohydrates and fat in 8 pounds of

corn and cob meal, and taking the total digestible nutrients in the given amounts of each of these substances we have the following trial ration:

RATION A.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Clover hay	15	1.02	5.37	.25
Corn and cob meal	8	.35	4.80	.23
Total nutrients in ration		1.37	10.17	.48
Nutrients required for a 1,000-lb. cow giving 30 lb. 4% milk		2.1	13.48	.58

By comparing the total nutrients in this ration with the required nutrients for a cow producing 30 pounds of 4 percent milk, it is found that the ration is deficient in both protein and carbohydrates. To bring the nutrients up to the amount required we try adding six pounds of bran and the ration is then as follows:

RATION B.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Clover hay	15	1.02	5.37	.25
Corn and cob meal	8	.35	4.80	.23
Bran	6	.73	2.35	.16
Total nutrients in ration		2.10	12.52	.64
Nutrients required for a 1,000-lb. cow giving 30 lb. 4% milk		2.10	13.48	.58

The amount of protein, carbohydrates, and fat now corresponds closely enough with the nutrients required, for all practical purposes.

If one wishes to feed clover hay, corn silage, corn meal, and ground oats, he can make up a trial ration by taking 8 pounds of clover hay, 40 pounds of silage, 4 pounds of corn meal, and 4 pounds of ground oats. The nutritive value of each of these feeds can then be

determined from the amount of digestible nutrients in 100 pounds given in the table on page 15. Taking the digestible nutrients in the given amounts of each of these substances we have the following trial ration:

RATION C. (Trial ration.)

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Clover hay	8	.54	2.86	.14
Corn silage	40	.36	4.52	.28
Corn meal	4	.31	2.67	.17
Ground oats	4	.37	1.89	.17
Total nutrients in ration		1.58	11.94	.76
Nutrients required for a 1,000-lb. cow giving 30 lb. 4 % milk		2.10	13.48	.58

By comparing the total nutrients in this ration with the required nutrients for a cow producing 30 pounds of 4 percent milk, it is found that the ration is deficient in both protein and carbohydrates, but needs a larger proportion of protein than of carbohydrates to bring the nutrients up to the amount required. Adding one pound each of corn meal, ground oats, and linseed meal, we have ration D, which is a good economical ration and fulfils the desired requirements.

RATION D.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Clover hay	8	.54	2.86	.14
Corn silage	40	.36	4.52	.28
Corn meal	5	.39	3.34	.22
Ground oats	5	.46	2.36	.21
Linseed meal	1	.29	.33	.07
Total nutrients in ration		2.04	13.41	.92
Nutrients required for a 1,000-lb. cow giving 30 lb. 4 % milk		2.10	13.48	.58

NUTRITIVE RATIO.

Since protein on the one hand and carbohydrates and fat on the other serve different functions in the body, the relative amount of each should be carefully considered, and the ratio of the protein to the carbohydrates, which is called the nutritive ratio, is determined in the following manner: The value of a pound of fat in feeds has been found to be 2.4 times that of a pound of carbohydrates, and as fat nourishes the body in the same way as carbohydrates, the amount of fat is multiplied by 2.4 and added to the carbohydrates; this sum divided by the amount of protein gives the ratio of the protein to the carbohydrates, and is known as the nutritive ratio.

This may be illustrated by taking the total digestible nutrients in trial ration C on page 7, which contains 1.58 pounds protein, 11.94 pounds carbohydrates, and .76 of a pound fat.

$$.76 \text{ of a pound fat} \times 2.4 = 1.82.$$

$$11.94 \text{ pounds carbohydrates} + 1.82 = 13.76.$$

$$13.76 \div 1.58 \text{ (amount of protein)} = 8.7.$$

Since there are 8.7 times as much carbohydrates as protein in this ration, the ratio is as 1 : 8.7; which is known as the nutritive ratio of this ration.

After adding one pound each of corn meal, ground oats, and linseed meal, we have ration D which contains 2.04 pounds protein, 13.41 pounds carbohydrates, and .92 of a pound fat. The nutritive ratio of this ration, found in the same manner as before, is as 1 : 7.6, which is nearer the ratio of the digestible nutrients required for a 1000 pound cow giving 30 pounds of 4 percent milk, as given in Table 1.

BALANCED RATION.

If the protein and the carbohydrates are in such proportion as will best suit the needs of the animal the ration is said to be balanced. If the amount of protein in the ration is small in proportion to the carbohydrates the ration is called wide; if the amount of protein is large in proportion to the carbohydrates, the ration is called narrow.

Since the needs of different animals vary greatly, it will be seen that a ration which is balanced for one animal or class of animals may be decidedly too wide or too narrow to be economical for another class. Young and growing animals and cows producing a large flow of milk require a much larger proportion of protein, or in other words a

narrower ration, than animals after they have completed their growth, or cows when giving a smaller flow of milk, or entirely dry. The difference in the amount of protein required by cows giving large and small flows of milk may be seen by referring to Table 1.

In feeding dairy cows several things must be considered besides the amount of digestible nutrients contained in the feed. The ration must be palatable and of such a nature that a cow can eat a sufficient quantity to supply her needs.

There is enough nutriment in 300 pounds of oat straw for a cow giving 60 pounds of 4 percent milk, but it would be absurd to expect a cow to produce such a yield on oat straw alone, as her capacity could not handle more than one tenth this bulk in one day. The concentrates, too, must be in the proper form to be best utilized by the cow. To get the most out of grains they should be ground, for the mastication is seldom, if ever, complete enough to break all the kernels, and those passing through the digestive tract unbroken are of no use to the animal and are, therefore, wasted. This difficulty may be partially obviated by mixing the grain and coarse fodder together. By feeding oats in the sheaf, or in the form of hay, or by mixing chopped hay with the grain it will be much more thoroughly masticated, as grain eaten with roughage passes to the rumen and is remasticated in chewing the cud.

RATION E. Roughage not palatable and Concentrates too heavy.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Corn stover	10	.17	3.24	.07
Oat straw	7	.08	2.70	.06
Corn meal	8	.62	5.34	.34
Linseed meal, N. P.	4	1.13	1.60	.11
Total nutrients in ration		2.00	12.88	.58
Nutrients required for a 1,000-lb. cow giving 30 lb. 4 % milk		2.10	13.48	.58
Nutritive ratio of ration E, 1: 7.1.				

It will be seen that this ration is correct so far as the chemical composition is concerned, but that the roughage is lacking in palata-

bility so that a cow will not relish it, and the concentrates, while highly nutritious, are what dairymen call too heavy. Oil meal is so highly concentrated that it should not be fed in large quantities. This ration should be lightened by adding some light bulky concentrate, as bran or ground oats, and made more palatable by substituting oat hay for oat straw. After making these slight changes we have Ration F, which is lighter and more palatable, yet contains practically the same amounts of the different digestible nutrients.

RATION F. An Economical Ration.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Corn stover.	10	.17	3.24	.07
Oat hay	7	.30	3.25	.11
Corn meal	6	.47	4.00	.26
Bran.	6	.73	2.35	.16
Linseed meal, N. P.	1	.28	.40	.03
Total nutrients in ration		1.95	13.24	.63
Nutrients required for a 1,000-lb. cow giving 30 lb. 4 % milk		2.10	13.48	.58
Nutritive ratio of ration F, 1 : 7.6.				

EXAMPLES OF PRACTICAL, ECONOMICAL RATIONS.

The rations given below are compounded so as to be palatable and at the same time have the proper chemical composition. They are suited to the needs of a 1000-pound cow giving 30 pounds of 4 percent milk, the same as the preceding ones, the requirements being 2.10 pounds protein, 13.48 pounds carbohydrates and .58 of a pound fat.

RATION G.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Clover hay	12	.82	4.30	.20
Corn silage	40	.36	4.52	.28
Corn meal	2	.16	1.33	.09
Oats	2	.18	.95	.08
Bran	2	.24	.78	.05
Gluten meal	1	.26	.43	.11
Total nutrients		2.02	12.31	.81
Nutritive ratio, 1 : 7.5.				

RATION H.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Corn silage	30	.27	3.39	.02
Cowpea hay	7	.76	2.70	.08
Oat hay	7	.30	3.25	.10
Corn and cob meal	5	.22	3.00	.14
Bran	3	.37	1.18	.08
Linseed meal, N. P	1	.28	.40	.03
Total nutrients		2.20	13.92	.45
Nutritive ratio, 1 : 6.8.				

RATION I.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Corn stover	10	.17	3.24	.07
Clover hay	8	.54	2.86	.14
Oat hay	8	.34	3.71	.12
Corn and cob meal	5	.22	3.00	.14
Bran	2	.24	.78	.05
Cotton-seed meal	2	.74	.34	.24
Total nutrients		2.25	13.93	.76
Nutritive ratio, 1 : 7.				

RATION J.

	Lb.	Digestible nutrients.		
		Protein, lb.	Carbohy- drates, lb.	Fat, lb.
Corn stover	10	.17	3.24	.07
Cowpea hay	10	1.08	3.86	.11
Corn and cob meal	7	.31	4.20	.20
Bran	4	.49	1.57	.11
Total nutrients		2.05	12.87	.49
Nutritive ratio, 1 : 6.8				

The farmer should, as a rule, aim to raise the greater portion of the feed for his stock on the farm. Since rough feed is usually much cheaper than grain, too much importance cannot be placed on securing hay and fodder in the best possible condition. If hay is unduly exposed to dew and rain during the time of curing it loses much, both in nutrition and palatability. It is also important that hay and fodder be cut at the proper stage, before becoming too ripe and the stems woody.

Leguminous plants, (those bearing their seeds in pods or legumes,) as clover, alfalfa, cowpeas, beans, etc., are rich in protein and should

be raised in sufficient quantities to supply the necessary protein for the stock. If the supply of protein is deficient some feed rich in that substance should be purchased to complete the ration.

Grain feed should not usually compose over half the ration, and from that to nothing, according to the character of the roughage available and amount of milk given by the cow. In general it is a safe rule to feed liberally on good roughage and vary the grain feed to suit the requirements of the individual.

When cows have luxuriant pasture during the late spring before the heat is excessive or the flies troublesome the conditions are as near ideal for dairy cows as it is easy to obtain. The nearer we can approach these conditions the year around the better for milk production. It is, therefore, essential to the best yields and most economical results that succulent food be provided for cows during the winter months. There are two ways of providing this succulent food—by silage and by root crops.

By comparing the results obtained at several different experiment stations it is found that corn commonly yields about twice as much nutrients per acre as do root crops. Since roots require much more hand labor, which is so expensive in this country, it is more economical for the Illinois farmer to get the succulent feed during the winter from corn silage than from root crops.

Silage is especially valuable on farms or in communities where rough feed is scarce, for more stock can be kept on a given area of land where the crops are made into silage than in any other way with the same amount of labor expended. No farmer keeping ten or more cows can afford to be without a silo.

GREEN FEED FOR SUMMER DROUGHT.

Dairymen suffer greatly nearly every summer by not supplying proper green feed for their cows during the hot dry weather of mid-summer. This shortage of feed comes at a very inopportune time since the cows are already beginning to feel the effect of the heat and flies which of themselves quite perceptibly lessen the flow of milk, and if feed is cut short at the same time the shrinkage is certain to be large, resulting in great loss, for it is practically impossible to restore the shrinkage during that period of lactation. A continuous supply of feed is equally essential to the successful maintenance of young and growing animals.

A pasture will carry much more stock during spring, early summer and fall than it will in the dry weather of mid-summer. By helping it out during this season with partial soiling the cattle have better feed and more stock can be carried on a given area than by pasturing alone. Such crops should be planted as will mature in proper succession with each in its best stage of growth, insuring a continuous supply of green feed during the dry season.

TABLE 2. CROPS FOR PARTIAL SOILING DURING MIDSUMMER.

Kinds of fodder.	Amount of seed per acre.	Approximate time of seeding.	Approximate time of feeding.
1. Corn—early, sweet or dent.	6 quarts	May 1	July 1—Aug. 1
2. Corn—medium dent	5 quarts	May 15	Aug. 1—Sept. 30
3. Cowpeas	1 bushel	May 15	Aug. 1—Sept. 30
4. Soy beans	1 bushel	May 15	Aug. 1—Sept. 15
5. Oats and Canada peas (each)	1 bushel	April 15	July 1—July 15
6. Oats and Canada peas (each)	1 bushel	May 1	July 15—Aug. 1
7. Rape (Dwarf Essex)	4 pounds	May 1	July 1—Aug. 1
8. Rape, second sowing	4 pounds	June 1	Aug. 1—Sept. 1
9. Rape, third sowing	4 pounds	July 1	Sept. 1—Oct. 1

For central and southern Illinois there is no crop that will produce more feed to the acre than corn, and by planting a small quantity of an early variety with the general crop, corn may be had in the proper condition for feeding from July 15 until frost. There are several early varieties that will mature for feeding in from sixty to seventy-five days after planting. Corn should not be fed too young. When it is nearly full height it contains only one-third as much nutriment as when in the roasting ear.

Some other crop should be fed in connection with corn to balance the ration and afford variety. Leguminous crops as clover, Canada, peas, cowpeas, soy beans, etc., are especially valuable for this purpose, being unusually rich in protein.

Cowpeas and soy beans give a large amount of valuable forage, furnishing feed from the first of August until frost. If more feed has been grown than can be fed green, it may be made into hay of excellent quality.

Oats and Canada peas yield well. They are not in condition to feed for more than two or three weeks but the supply may be length-

ened by sowing at different dates. If a portion becomes too ripe it may be utilized by making it into hay.

If the pastures are short and no allowance has been made for green feed, corn cut from the regular crop, if it is near the roasting ear stage, will bring the best of returns. Never under any consideration allow the stock to go hungry and suffer the losses incident to shortened feed at a time which for every reason is the most trying to live stock.

Those who wish to study this subject further are referred to some of the standard books on feeding; among the best being "Feeds and Feeding" by Professor Henry, Director of the Agricultural Experiment Station, at Madison, Wisconsin; and "Feeding Farm Animals" by Dr. Jordon, Director of the Agricultural Experiment Station at Geneva, New York. The former gives a very complete description of the results of feeding investigations both in this country and abroad; the latter is a well written popular treatise upon the subject of feeding.

TABLE 3. AVERAGE AMOUNT OF DIGESTIBLE NUTRIENTS IN AMERICAN FEEDING STUFFS. FROM HENRY'S "FEEDS AND FEEDING."

	Digestible nutrients in 100 lb.		
	Protein, lb.	Carbohy- drates, lb.	Fat, lb.
CONCENTRATES.			
Dent corn	7.8	66.7	4.3
Sweet corn	8.8	63.7	7.0
Corn and cob meal	4.4	60.0	2.9
Corn bran	7.4	59.8	4.6
Gluten meal	25.8	43.3	11.0
Germ meal	9.0	61.2	6.2
Grano-gluten	26.7	38.8	12.4
Hominy chops	7.5	55.2	6.8
Gluten feed	20.4	48.4	8.8
Wheat	10.2	69.2	1.7
Wheat bran	12.2	39.2	2.7
Wheat shorts	12.2	50.0	3.8
Wheat middlings	12.8	53.0	3.4
Rye	9.9	67.6	1.1
Rye bran	11.5	50.3	2.0
Rye shorts	11.9	45.1	1.6
Barley	8.7	65.6	1.6
Brewers' grains, wet	3.9	9.3	1.4
Brewers' grains, dried	15.7	36.3	5.1

TABLE 3—Continued.

	Digestible nutrients in 100 lb.		
	Protein, lb.	Carbohy- drates, lb.	Fat, lb.
CONCENTRATES—continued.			
Oats	9.2	47.3	4.2
Oat feed or shorts	12.5	46.9	2.8
Oat dust	8.9	38.4	5.1
Oat hulls	1.3	40.1	0.6
Buckwheat bran	7.4	30.4	1.9
Buckwheat middlings	22.0	33.4	5.4
Flax seed	20.6	17.1	29.0
Lindseed meal, old process	29.3	32.7	7.0
Linseed meal, new process	28.2	40.1	2.8
Cotton seed	12.5	30.0	17.3
Cotton-seed meal	37.2	16.9	12.2
Cottons-seed hulls	0.3	33.1	1.7
Peas	16.8	51.8	0.7
Soy bean	29.6	22.3	14.4
Cowpea	18.3	54.2	1.1
Horse bean	22.4	49.3	1.2
ROUGHAGE.			
Fodder corn, green	1.0	11.6	0.4
Fodder corn, field-cured	2.5	34.6	1.2
Corn stover, field-cured	1.7	32.4	0.7
FRESH GRASS.			
Pasture grasses (mixed)	2.5	10.2	0.5
Kentucky blue grass	3.0	19.8	0.8
Timothy, different stages	1.2	19.1	0.6
Orchard grass, in bloom	1.5	11.4	0.5
Redtop, in bloom	2.1	21.2	0.6
Oat fodder	2.6	18.9	1.0
Rye fodder	2.1	14.1	0.4
Sorghum	0.6	12.2	0.4
Meadow fescue, in bloom	1.5	16.8	0.4
Hungarian grass	2.0	16.0	0.4
Green barley	1.9	10.2	0.4
Peas and oats	1.8	7.1	0.2
Peas and barley	1.7	7.2	0.2
HAY.			
Timothy	2.8	43.4	1.4
Orchard grass	4.9	42.3	1.4
Redtop	4.8	46.9	1.0
Kentucky blue grass	4.8	37.3	2.0
Hungarian grass	4.5	51.7	1.3
Mixed grasses	5.9	40.9	1.2
Meadow fescue	4.2	43.3	1.7
Soy-bean hay	10.8	38.7	1.5
Oat hay	4.3	46.4	1.5

TABLE 3—Continued.

	Digestible nutrients in 100 lb.		
	Protein, lb.	Carbohy- drates, lb.	Fat, lb.
STRAW.			
Wheat	0.4	36.3	0.4
Rye	0.6	40.6	0.4
Oat	1.2	38.6	0.8
Barley	0.7	41.2	0.6
FRESH LEGUMES.			
Red clover, different stages	2.9	14.8	0.7
Alsike, bloom	2.7	13.1	0.6
Crimson clover	2.4	9.1	0.5
Alfalfa	3.9	12.7	0.5
Cowpea	1.8	8.7	0.2
Soy bean	3.2	11.0	0.5
LEGUME HAY AND STRAW.			
Red clover, medium	6.8	35.8	1.7
Red clover, mammoth	5.7	32.0	1.9
Alsike clover	8.4	42.5	1.5
White clover	11.5	42.2	1.5
Crimson clover	10.5	34.9	1.2
Alfalfa	11.0	39.6	1.2
Cowpea	10.8	38.6	1.1
Soy-bean straw	2.3	40.0	1.0
Pea-vine straw	4.3	32.3	0.8
SILAGE.			
Corn	0.9	11.3	0.7
Clover	2.0	13.5	1.0
Sorghum	0.6	14.9	0.2
Alfalfa	3.0	8.5	1.9
Grass	1.9	13.4	1.6
Cowpea vine	1.5	8.6	0.9
Soy bean	2.7	8.7	1.3
Barnyard millet and soy bean	1.6	9.2	0.7
Corn and soy bean	1.6	13.0	0.7
ROOTS AND TUBERS.			
Potato	0.9	16.3	0.1
Beet, sugar	1.1	10.2	0.1
Beet, mangel	1.1	5.4	0.1
Flat turnip	1.0	7.2	0.2
Rutabaga	1.0	8.1	0.2
Carrot	0.8	7.8	0.2
Parsnip	1.6	11.2	0.2
Artichoke	2.0	16.8	0.2
MISCELLANEOUS.			
Cabbage	1.8	8.2	0.4
Pumkin, field	1.0	5.8	0.3
Pumkin, garden	1.4	8.3	0.8

TABLE 3—Continued.

	Digestible nutrients in 100 lb.		
	Protein, lb.	Carbohy- drates, lb.	Fat, lb.
MISCELLANEOUS—continued.			
Prickly comfrey	1.4	4.6	0.2
Rape	1.5	8.1	0.2
Dried blood	52.3	.0	2.5
Meat scrap	66.2	.3	13.7
Beet pulp	0.6	7.3	.....
Beet molasses	9.1	59.5	.....
Cow's milk	3.6 *	4.9	3.7
Cow's milk, colostrum	17.6	2.7	3.6
Skim milk, gravity	3.1	4.7	0.8
Skim milk, centrifugal	2.9	5.2	0.3
Buttermilk	3.9	4.0	1.1
Whey	0.8	4.7	0.3

CIRCULAR No. 78
AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF ILLINOIS.

CLEAN MILK.

BY WILBER J. FRASER, Chief in Dairy Husbandry.

Unless carefully produced, milk is impure, and is often unfit for human food. It is subject to contamination in so many ways in the course of its production and distribution, that it is practically impossible for the customer to secure it entirely free from filth, dust, and germs, except when produced and handled with the utmost care. Since it is an ideal medium for the growth of bacteria, the greatest precaution should be observed that no germs, especially those causing disease, gain access to it. There is no secret connected with the production of sanitary milk. Cleanliness in every operation, from first to last, and thorough cooling as soon as drawn are the only requisites. The result is nothing more nor less than simply *clean milk*.

WHICH WAY IS THE HERD CARED FOR THAT IS PRODUCING YOUR MILK ?



AN UNGRADED YARD IN WHICH THE MANURE IS ALLOWED TO ACCUMULATE AND THE COWS ARE OBLIGED TO WADE KNEE DEEP IN THE FILTH EVERY DAY.



A WELL-GRADED YARD COVERED WITH SIX INCHES OF CINDERS FORMING A
HARD SURFACE, THUS KEEPING THE COWS OUT OF THE MUD.

STANDARDS FOR GOOD MILK.

Any milk that shows a sediment on the bottom of a transparent vessel upon standing one hour is not fit for human food. The consumer has a right to demand that the milk furnished him be clean; that it keep at least twenty-four hours after being delivered to the consumer, if held at a temperature of 60° F. or below; that it contain no disease-producing germs or any form of preservative; and that it have a certain known composition, which is uniform from day to day.

THE VALUE OF GOOD MILK.

Milk that is free from dirt, and in which the bacterial content is exceptionally small, is a healthful and economical food; such milk is essential for infants and invalids, besides being much more healthful and palatable for all. In fact, a clean milk supply is just as necessary to correct living as is a pure water supply or wholesome food of any kind.

The question, then, of an improved milk supply rests not only with the producers, but largely with the consumers as well, and when they demand clean milk, and are willing to pay the extra cost of production, such milk will be supplied. Even at an advanced price, milk is cheaper than meat when food equivalents are fully considered.

THE BARNYARD.

In the production of clean milk no one thing is of more importance than keeping the cows out of the filth. Many yards into which dairy cows are turned each day for their drink and exercise are knee-deep with mud and manure during the winter and spring, if not nearly the entire year. In summer when the cows are on pasture they would keep comparatively clean were they not obliged to wade through a filthy yard in going to the stable for milking.

The yard should slope from the barn, and be covered with gravel or cinders sufficiently deep to form a hard surface. Manure should not be allowed to accumulate against or near the barn, and no swine pen should be nearer than two hundred feet on account of the odors from it being readily absorbed by milk.

WHICH COW REPRESENTS THE SOURCE OF YOUR MILK SUPPLY?



AFTER A RUN OF THREE WEEKS ON PASTURE, IMAGINE THE
FILTHY CONDITION DURING WINTER!

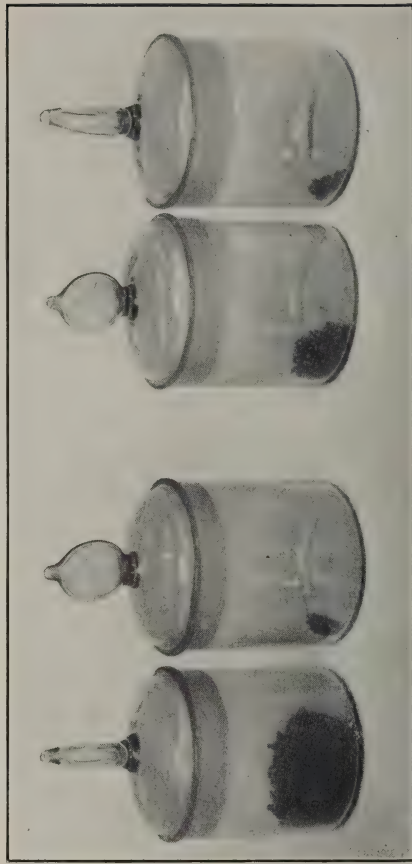
HOW MUCH MORE WOULD YOU PAY FOR MILK FROM COWS
KEPT LIKE THIS ONE?



CLEAN EVEN IN MIDWINTER.

AMOUNTS OF DIRT CAUGHT UNDER WASHED AND UNWASHED UDDERS DURING MILKING.

UDDER MUDDY. AFTER WASHING. UDDER SLIGHTLY SOILED. BEFORE WASHING. AFTER WASHING.

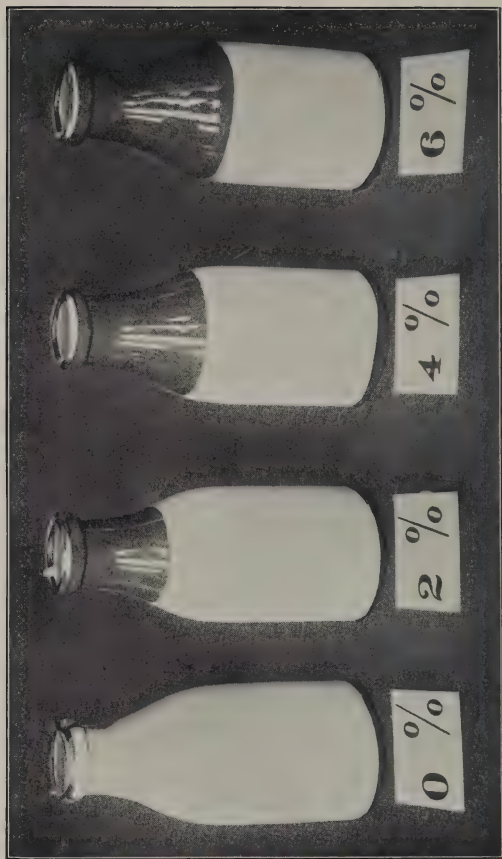


THE AVERAGE WEIGHT OF DIRT WHICH FALLS FROM MUDDY UDDERS DURING MILKING IS 90 TIMES AS GREAT AS THAT WHICH FALLS FROM THE SAME

UDDERS AFTER WASHING, AND WHEN UDDERS ARE SLIGHTLY SOILED IT IS 18 TIMES AS GREAT.

NECESSITY OF WASHING UDDERS BEFORE MILKING.

Milk as ordinarily produced gets the greatest amount of contamination during milking from udders not washed. To determine the amount of filth that gets into milk in this way, seventy-five trials were made at different seasons of the year with three classes of udders, those apparently clean, those soiled, and those muddy. With udders that were apparently clean, it was found that an average of three and one-half times as much dirt fell from the unwashed udders as from the same udders after they were washed. With soiled udders the average was eighteen, and with muddy udders ninety times as much dirt from the unwashed as from the washed.



STANDARDIZED MILK, SHOWING THE AMOUNT OF CREAM ON MILK CONTAINING THE DESIGNATED PERCENT OF BUTTER FAT.

STANDARD MILK.

By standard milk and cream is meant that which has a certain known composition, thus establishing a true basis for valuation.

Let it be clearly understood by producers, consumers, city councils, and everybody that in these days the dealer can furnish the customer with milk of any desired richness, without regard to the quality ordinarily yielded by the cow, and all milk should be either so standardized, or else bought and sold according to its natural composition.

Selling milk by measure without regard to quality is unjust to the producer as well as to the consumer. While the fallacy of the system is apparent to a few, the majority of people seem to think that milk is milk, and that one quart is worth as much as another, so long as it is still sweet.



SERVING A DAIRY LUNCH TO THE STATE DAIRYMEN'S ASSOCIATION IN UNIVERSITY
OF ILLINOIS DAIRY BARN, JANUARY 6, 1903.

REFRESHMENTS SERVED IN DAIRY BARN.

At the meeting of the Illinois State Dairymen's Association, held at the College of Agriculture, refreshments were served in the dairy barn; the object being to impress upon the dairymen of the state the fact that dairy barns are places where human food is produced, and that they should, therefore, be fit places in which to prepare and eat food as well.

THE CONSUMER'S RESPONSIBILITY.

That milk may reach the table in first-class condition, the consumer has responsibilities as well as the producer. The milkman is frequently blamed for many things for which he is not responsible. However perfect the condition and low the temperature of the milk when delivered,

it cannot long remain in good condition unless carefully handled. If milk is to keep, it must be stored in utensils that have been thoroughly washed and scalded and held at a low temperature, at least 60° F., and below if possible.

If milk is not delivered in bottles, care must be taken to protect it from dust, and it must be placed where there are no odors to be absorbed. Bottled milk, being sealed with a pulp cap, cannot absorb odors, and *should be left in the bottle until used*, not emptied into an open dish.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

URBANA, JULY, 1904.

CIRCULAR NO. 79.

PRESENT METHODS OF BEEF PRODUCTION.

I.

BY HERBERT W. MUMFORD, CHIEF IN ANIMAL HUSBANDRY, AND
LOUIS D. HALL, FIRST ASSISTANT IN ANIMAL HUSBANDRY.

INTRODUCTION.

Approximately 3,000 to 4,000 farmers of Illinois are extensively engaged in beef production in one of its two branches, viz., breeding cattle for the production of beef or fattening for market cattle previously bought as stockers or feeders. The number of cattle marketed annually by them varies within the approximate limits of 200,000 and 300,000 head. The number of cattle on Illinois farms January 1, 1904, was 2,689,193.* Consequently a yearly saving of one dollar per head in the feeding, management, buying or selling of the cattle of the state would result in the addition of over two and one half millions of dollars annually to the net income of Illinois beef producers. That such a percentage of improvement is much less than the difference existing between the most improved and the most common methods now practiced in the state, few will question. That a still larger saving can be effected by more thorough knowledge of the principles and more careful attention to the details of beef production is reasonable to assume.

*U. S. Department of Agriculture, Year Book, 1903.

PLAN OF INVESTIGATION.

The investigation of which this circular is a partial report was undertaken in order to determine the methods now commonly pursued in beef production in the corn-growing states, to bring to light as much as possible of the experience and data which have been accumulated by cattle feeders in the corn belt and to give out this information in such a form as to be of practical benefit to the beef producer. One hundred questions were submitted by mail to each of about two thousand five hundred cattle feeders in Illinois and to about three thousand five hundred in neighboring states.* It was the purpose to so word the questions as to call for replies based in each instance upon the feeder's entire experience in beef production. Thus the inquiry dealt with general conditions and not merely those existing at the time of receiving the replies, and the results secured therefore have a wide range of application. In order to make the investigation as thorough as possible in Illinois the Secretary of the Farmers' Institute of each county in the state was asked to furnish a list of the cattle feeders in his county whether engaged in breeding for market, in feeding only, or both. In addition to the questions sent to each man whose address was thus secured, a blank form and stamped envelope were inclosed, with a request to give the addresses of all cattle feeders in that locality. The process was then repeated with the names thus obtained. Some of the addresses, and particularly those in other states, were furnished by Chicago live stock commission firms. Some also were secured from agricultural and special journals reporting the live stock market.

*For list of questions see Circular No. 65, Illinois Agricultural Experiment Station.

DATA SECURED.

The following list shows the number of feeders addressed and the number of replies received from each county:

COUNTY.	Ad-dressed.	Replies.	COUNTY.	Ad-dressed.	Replies.
Adams	19	2	Livingston.	19	3
Alexander	1	0	Logan	20	4
Bond	3	0	McDonough	34	7
Boone	19	3	McHenry	3	0
Brown	16	3	McLean	63	15
Bureau	42	11	Macon	34	5
Calhoun	3	0	Macoupin	55	10
Carroll	26	3	Madison.	9	1
Cass	42	9	Marion	3	0
Champaign	40	6	Marshall	27	6
Christian	11	2	Mason	34	7
Clark	17	2	Menard	65	17
Clay	12	3	Mercer	3	0
Clinton	8	2	Massac	12	3
Coles	76	21	Monroe	11	0
Cook	8	2	Montgomery	22	3
Crawford	0	0	Morgan	72	19
Cumberland	9	1	Moultrie	38	6
DeKalb	29	6	Ogle	23	8
DeWitt	19	5	Peoria	6	0
Douglas	25	3	Perry	6	1
Dupage	0	0	Piatt	38	9
Edgar	40	12	Pike	67	13
Edwards	9	3	Pope	2	1
Effingham	16	4	Pulaski	8	2
Ford	2	0	Putnam	19	5
Fayette	0	0	Randolph	15	2
Franklin	7	1	Richland	9	0
Fulton	53	11	Rock Island	1	1
Gallatin	8	1	Saline	22	1
Greene	76	20	Sangamon	24	3
Grundy	23	8	Schuyler	6	0
Hamilton	4	0	Scott	55	16
Hancock	136	25	Shelby	15	2
Hardin	33	7	Stark	27	5
Henderson	45	5	Stephenson	7	3
Henry	50	18	St. Clair	0	0
Iroquois.	42	7	Tazewell	18	7
Jackson	23	5	Union	48	9
Jasper	14	0	Vermilion	47	9
Jefferson	9	2	Wabash	19	4
Jersey	22	5	Warren	27	8
Jo Daviess.	30	0	Washington	4	0
Johnson	22	3	Wayne	40	14
Kane	17	3	White	20	3
Kankakee	21	9	Whiteside	15	3
Kendall	29	5	Will	8	1
Knox	2	0	Williamson	12	0
Lake	7	0	Winnebago	64	15
LaSalle	30	8	Woodford	22	8
Lawrence	10	3			
Lee	28	7	Total	2451	509

It will be observed that in several cases counties in which beef production is a very small factor have furnished a larger number of names and replies than other counties in which cattle feeding is a leading feature. This indicates that the greatest disposition to seek information is often found in those sections where the industry is of least extent and importance, while localities in which it is a prominent factor and which should have the greatest interest in matters pertaining to it are frequently most indifferent. It should be borne in mind, however, that the number of cattle feeders in a county is not a reliable indication of the extent of the feeding industry in that county, since the average number of cattle fed by each individual varies widely in different localities. It should also be observed in this connection that those sections in which beef production has been longer established have not as great need of information on the subject as those in which the business is comparatively undeveloped.

SCOPE OF THE INVESTIGATION.

The practical experience of the Illinois cattle feeders who replied amounts to a total of 7,072 years and involves the feeding and marketing of over 627,000 cattle. In addition replies were received from about 600 feeders in other states whose experience aggregates approximately 7,000 years and represents the feeding of more than 686,000 cattle. The investigation therefore covers the experience of over 1,100 men, amounting to more than 14,000 years of practical experience in beef production, during which time a total of more than 1,350,000 cattle were fed. In view of the variation in conditions affecting beef production in different states, this report will be confined to the investigation in Illinois, except when otherwise stated.

The average number of cattle fed annually by our correspondents in Illinois, as can be calculated from the figures given above, is about 88 head. In fact we find that nearly 60 percent of the men who replied feed more than 100 cattle each annually, while only 14 percent feed less than 40 head. The fact that the more extensive feeders have contributed most largely to the data which form the basis of this report, greatly increases its value.

CONDITIONS CONSIDERED ESSENTIAL TO INCREASED RETURNS.

No question in beef production admits of argument to a greater extent than that of the changes of conditions necessary in order to render it more profitable, and it is conservative to say that never has this problem been of greater moment to the producer of beef in Illinois than at the present time. The sentiments concerning the ques-

tion as expressed by 366 feeders and breeders of cattle in Illinois are given below. One hundred and forty three of those who replied to other questions made no reply to the one under consideration. Most of the replies included several points, and these are listed below, together with the number of men who mention each point:

More well-bred cattle	203
Mature the cattle earlier	21
Cheaper stockers and feeders	42
Higher price for fat cattle	34
Lessen the expense of marketing	10
Greater demand for beef	10
Make the cattle fatter	6
More uniform markets	4
Better knowledge of market conditions	1
More intelligent use of feeds	79
Cheaper feed	42
Cheaper land	19
More land sown to grass	23
Better pastures	17
Better crops	14
More careful use of manure	15
More clover	8
Better care of cattle	26
Better shelter, and extermination of flies and lice	27
Better and cheaper labor	4
Remove range competition	5
Cheaper transportation for range feeders	3
Improved financial conditions	4
Conditions are satisfactory	2
Don't know	20
	639

A very significant fact brought out in the above summary is that a large percentage of Illinois breeders and feeders of cattle are convinced of the need of better blood in the herds and feed lots of the state. It is noteworthy, also, that next in importance to proper breeding, our correspondents emphasize the more intelligent use of feeds. This sentiment among our beef producers promises well for the improvement of the industry in Illinois. It is believed, however, that

the point mentioned by only one of those who replied, viz., "A better knowledge of market conditions," is deserving of far greater attention than it has yet received by producers of beef, and that a more thorough understanding of the demands of the trade is essential to the greatest success in supplying those demands.

Some of the questions submitted were general in character, hence the replies to such cannot be reduced to mathematical terms. Indeed a numerical summary of the results of an investigation of this kind would be entirely inadequate, and in some respects might even be misleading. It is considered advisable, therefore, not to present all the replies in statistical form, but to report the conclusions therefrom in a series of papers based on a careful study of the replies referred to above. In this circular, which is the first of a proposed series, is reported that portion of the results relating to

STOCKERS AND FEEDERS.

It has been estimated by men who are in close touch with the beef trade that only about fifteen per cent of the native beef steers marketed in Chicago are carried from birth to maturity without changing hands. In other words about eighty-five per cent are bought as stockers or feeders by men who fatten them for the market. This estimate seems to be borne out by the data secured in this investigation.

The land occupied by our correspondents varies in value from \$20 to \$120 per acre. Sixty-two per cent of those who reply give values ranging from \$70 to \$100 per acre, 28 percent below \$70 and 10 percent above \$100. (These are 1902 values.) From a study of the data secured the conclusion is drawn that there is no constant relation between the value of the land in any locality and the proportion of cattle either bred or fed for beef in that locality. However, when we consider the number of men engaged in breeding and feeding respectively we find that on lands ranging from \$70 to \$100 in value, the ratio of the number engaged in mere feeding to the number who breed the cattle which they fatten, is very much larger than on lands of lower value. Since only a fraction of the beef producers of the state are represented by our data, the figures presented on this point are not to be considered as absolutely exact or conclusive; but it may be stated that on the basis of the replies received, the ratio of the number of men who buy their feeders to those who breed them, on land valued at \$70 to \$100, is about as 12 to 1, while on land ranging in value from \$20 to \$70, the ratio is about as $2\frac{1}{2}$ to 1.

Another factor that is sometimes said materially to affect the buying of stockers and feeders as against raising them is the distance from the cattle markets. A study of the data secured in this investigation leads to the conclusion that the factor named has no uniform influence in the matter; in other words, that the preponderance of either method varies independently of distance from the leading cattle markets. Neither can it be said that beef production is most extensive in those parts of the state which are most available to the leading markets. The conclusion appears to be warranted, however, that the principal beef-producing sections are those in which corn is grown most extensively.

WINTERING STOCKERS.

In buying stockers a common practice is to buy cattle during the fall and early winter that are thin in flesh and weigh from 500 to 800 pounds, winter them on a ration calculated merely to keep them from shrinking in weight, and either fatten with grain or grass during the summer or graze them through the pasturing season and finish on grain the following fall. Thus we find that more than two-thirds of our correspondents buy their stockers and feeders in the fall and winter. The reason given by the great majority of these is that the cattle can be bought more cheaply at that time. Practically all of the remainder buy in the spring, and the statement is made in some instances that while the market is usually lower on stockers and feeders during the fall and early winter, the expense of wintering often brings the final cost per hundred weight to a point above the price commanded by the same cattle in the spring. By "expense of wintering" is meant feed, labor, interest, taxes and mortality.

The experience of some of our correspondents indicates that stockers carried through the grazing season on pasture will yield larger returns during that time if previously maintained through the winter on roughage than if fed a liberal ration of grain for several months before pasturing. The former method is often found most economical in localities which are naturally adapted to the growing of grass and forage crops largely to the exclusion of grain. But under average Illinois conditions it is rarely found good economy to carry stockers a considerable time on a mere maintenance allowance, even though the subsequent gain on grass be thereby increased. The average daily gain secured with yearlings on grass alone through the grazing season is variously stated by 161 of our correspondents. The mean of these is 1.66 pounds. For two-year-olds on grass alone the average daily gain, based on 170 replies, is 1.87 pounds.

SOURCES OF STOCKERS.

In reply to the question, "Where do you buy your stockers?" more than one-half of our correspondents replied that their cattle were bought in their own neighborhood, and practically all of the remainder in Chicago, Kansas City, St. Louis or Omaha. Those who buy locally give various reasons for their preference, of which the more frequently mentioned are (1) better acquaintance with the dealers and with the breeding of the cattle; (2) better cattle can be secured; (3) cattle can be bought nearer worth the money because freight, shrinkage, commission and other expenses incident to buying in the open market are saved; (4) the cattle are not bruised and gaunted by shipping; (5) the cattle are accustomed to the climate and usually to grain feeding.

Those who buy at the markets give as reasons for their preference (1) the market affords a larger number from which to select, hence the kind wanted can more often be obtained and more uniformity in weight, quality and condition can be secured; (2) the cattle can often be bought cheaper, due to oversupply or lack of demand, while the price in the country is more inflexible; (3) can get better cattle.

A study of the replies to the above question leads to the conclusion that the differences in opinion which appear are largely dependent upon the number of cattle handled by the individual. The extensive feeder prefers the market as a source of supply, while the man who carries but a few cattle usually finds that he can buy at home more advantageously.

BREED, AGE, WEIGHT AND CONDITION.

As to the breed most in favor as stockers and feeders, about 50 percent of our correspondents state that Shorthorns have given the best returns; 20 percent favor the Hereford breed, 18 percent Angus, and the remainder are divided among other breeds and grades. A number state that their choice would be any of the beef breeds. The apparently greater popularity here shown in favor of the Shorthorn breed should not be misconstrued. The average Illinois feeder has a better opportunity to become familiar with them than with other pure-bred cattle by reason of the fact that they are the most numerous breed in this and neighboring states. Consequently the fact that they are in greater favor than others cannot be said to be altogether due to choice or merit, but must be attributed to a certain extent to their greater numbers and wider distribution.

Almost 50 percent of those who replied state that two years is the age preferred for stockers and feeders, the remainder being about equally divided above and below two years. In reply to the question, "At what age do you find it pays to put steers on full grain feed?" the answers include ages from two months to four years. About 50 percent prefer the age of two years, about 35 percent above and the remainder below that age.

In regard to the weight of stockers and feeders which gives best returns, 40 percent of our correspondents favor weights from 800 to 1,000 pounds; 26 percent favor less than 800; 20 percent 1,000 pounds and 14 percent more than 1,000 pounds.

With reference to the condition of flesh desired in stockers or feeders we find a great variety of replies. Thus out of 386 replies 147 answer "good;" 80, "medium;" 90, "fair;" 63, "thin;" 6, "fat."

"Do you ever feed spayed or open heifers?" Less than one-third of our correspondents reply affirmatively to this question. Of those who sometimes use heifers as feeders about one-half report that they have been able to realize as much profit from feeding them as from feeding steers.

CLASS OF BEEF PRODUCED.

"What class of beef do you attempt to produce?" was asked our correspondents, with a view of ascertaining the prevalent use of terms relating to cattle market classifications, as well as to secure data on the subject suggested by the question. The various classes given, and the number of replies received for each, were as follows:

CLASS.	No. of replies	CLASS.	No. of replies
Best	83	Good	92
Export	41	Fair to good	1
First class	33	Fair	12
Choice	13	Medium	40
Shipping steers	3	Second class	10
Dressed beef	11	Third grade	1
Baby beef	10	Common	3
Fat	2	Butcher stuff	5

It is apparent from the foregoing miscellaneous replies that greater precision and uniformity in the use of market terms would be not only desirable but also of tremendous advantage to the cattle feeder, resulting in a clearer conception of market demands and thus

a more definite aim in the production of beef. It should be understood that the name of the class to which a beef animal belongs refers to the use to which the animal is put. *The classes of cattle are Beef, Butcher Stock, Cutters and Cannery, Stockers and Feeders, and Veal Calves. The names of the grades within each class describe the degrees of conformity to the standard for that class. Thus the grades of stockers and feeders are fancy selected, choice, good, medium, common and inferior. The use of the terms fair, poor, extra and similar terms of an indefinite nature is to be discouraged.

*For a complete outline and description of the market classes and grades of cattle the reader is referred to Bulletin No. 78 of the Illinois Agricultural Experiment Station. Bulletin No. 90 of the same station gives an account of the fattening of a carload of feeders of each grade.

UNIVERSITY OF ILLINOIS

Agricultural Experiment Station.

CIRCULAR NO. 82.

THE PHYSICAL IMPROVEMENT OF SOILS.

(WITH SPECIAL REFERENCE TO THE VALUE OF ORGANIC MATTER.)

By J. G. MOSIER.



URBANA, ILLINOIS, OCTOBER, 1904.

FACTORS IN CROP PRODUCTION.

BY CYRIL G. HOPKINS, CHIEF IN AGRONOMY AND CHEMISTRY.

There are six absolute essentials in the growing of crops; namely:

- (1) The seed.
- (2) The home, or lodging place.
- (3) The food.
- (4) The drink, or moisture.
- (5) The heat.
- (6) The light.

Every plant of corn, oats, wheat, etc., requires each of these six essentials; and maximum crop yields are obtained when all of these factors exist in a perfectly balanced relation with respect to the needs of the growing crop, the crop not being subjected to injury by weeds, insects, disease, etc. Any one of these factors may limit the yield of a crop. Consequently, the true art and science of agriculture requires consideration for every essential factor, injury to the plant also being guarded against.

Poor seed will inevitably produce a poor crop. Good seed is exceedingly important, but not more so than a suitable lodging place for the plants; and no matter how good the seed or how perfect the physical condition of the soil, plants cannot grow without food and moisture and heat and light. Determine the limiting factor—the factor which limits the crop yield—and then remove this limitation by providing that essential in greater abundance or perfection.

We may have light sufficient for a 200-bushel crop of corn, heat sufficient for a 200-bushel crop, and abundant rainfall for a 200-bushel crop, and yet the soil, the home of the plant, may be so hard and compact and impervious to plant roots, so non-absorbent and non-retentive of moisture as to limit the yield to 20 bushels an acre, even with good seed and abundance of plant food; or the soil may be in perfect physical condition, furnishing the plants an ideal lodging place, with light, heat, and moisture provided in abundance for a 200-bushel crop, and yet the supply of plant food, even of one element of plant food, may be so limited as to hold down the crop yield to 20 bushels an acre.

These are practical, scientific, agricultural facts. This circular, No. 82, by Professor Mosier, is designed to furnish to Illinois farmers some useful information, especially relating to soil physics and management. It is preliminary to more specific and technical bulletins which are to follow, giving the detailed results of experiments and investigations relating to these subjects.

THE PHYSICAL IMPROVEMENT OF SOILS.

WITH SPECIAL REFERENCE TO THE VALUE OF ORGANIC MATTER.

BY J. G. MOSIER, ASSISTANT CHIEF IN SOIL PHYSICS.

(For information concerning the origin of soil material, the strata of the soil, and the constituents composing soils, the reader is referred to the Appendix.)

ORGANIC MATTER.

If a soil is examined closely it will be found to contain organic material (fragments of plants), some of which can still be recognized readily as of vegetable origin, while the most of it has decomposed to such an extent that it has lost its vegetable structure and original chemical composition. Organic matter in this latter form is called humus.

This vegetable material is derived from various parts of plants, as roots, stems, and leaves, and has been incorporated in the soil by various agencies. This mixing of organic matter in the soil has been effected to some extent by insects, earthworms, and burrowing animals, all of which carry parts of plants into their underground homes, as well as bring some of the subsoil upon the surface where it is mixed with vegetable matter. But the chief manner in which this is introduced into the soil in a natural way is by the growth and death of roots, especially of the grasses and clovers. What a mass of roots form in a bluegrass or timothy sod! The same thing is true of the wild prairie grasses that once grew so abundantly on our prairie soils. These roots penetrated the soil to a depth of from ten inches to eighteen inches; and, as many new roots grew and died during each year, or series of years, a constant accumulation of organic matter was taking place. These dead roots, being cut off to a considerable extent from the oxygen of the air by the overlying soil and the moisture it contained, did not decompose as rapidly as the new material was added. On the higher ground where the grass grew less luxuriantly and where decay was not hindered so much by a large moisture content in the soil, the organic matter content did not increase so rapidly and as a result the color of the top soil is brown or light brown. On the low ground, which was swampy for a large part of the year, the grasses grew more luxuriantly and the water largely prevented the decay of the dead plants. The organic matter accumulated here, giving the soil a dark brown or black color. The timber soils of this state, except in bottom lands, are generally deficient in organic matter as shown by the light, or almost white, color, while the prairie

soils are brown or black. This difference in organic matter content is largely due to the difference in vegetation found upon the two types. The organic matter in forests is added almost entirely to the surface of the soil in the form of leaves and broken twigs, and in a climate such as ours, complete decay is very likely to take place where vegetation is exposed to the air. Timber soils in this state usually have good natural drainage, and the removal of the water tends to aid decomposition, hence we find them very light in color.

In many low places in the northern and north-central parts of the state, some soils are made up almost entirely of organic matter. These are called peaty soils when the organic matter content reaches twenty-five percent or more of the dry weight of the soil. These peaty soils were formed from the growth of grasses, sedges, and moss under conditions of moisture that prevented the decay of the dead plants. There are indications that nearly all of the peat of this state was formed from grasses and sedges, while that of colder regions is formed from moss. (Some moss peat is found in the extreme northern part of Illinois.) Peat moss requires a large amount of moisture for its growth, and the lower part of the plant dies as rapidly as the top grows, and this lower part being prevented from decaying by the moisture, may accumulate to a depth limited only by moisture and drainage. Peat from grasses and sedges is formed by the accumulation of the dead material, both roots and tops.

Peaty soils vary in the amount of inorganic material that they contain. Under some conditions considerable amounts of clay, silt, or sand may be carried into these swamps by wind or water, or both, and as a result, soils will be formed with varying amounts of these constituents. Peaty swamp lands frequently require some special treatment to make the soil productive. (See Bulletin No. 93.)

Good productive soils should contain from five percent to ten percent of organic matter in the surface seven inches, or from fifty to one hundred tons in an acre. Soils with different physical composition are likely to have different amounts of organic matter. Clay and silt soils tend to accumulate more organic matter than sandy or loose soils. This is because more perfect ventilation or aeration will allow more rapid and more complete decay in sandy soils. Oxygen, the element that must be present for decomposition to take place, readily enters the loose sandy soil, but is largely excluded from the finer, more compact clayey and silty soils, so that decay goes on very slowly in these. The organic matter is the only variable constituent of soils. The amounts of sand, silt, or clay are practically the same in the same soil for all time. Then the only way by which we may change the physical composition of our soils is by changing the amount of organic matter, and this we can do if we will. Very few sections of our state have such an over abundance of organic

matter in the soils that its maintenance may be neglected. At least half of the soils of the state need a larger amount of organic matter than they now contain to render them productive to the highest degree.

The value of organic matter lies in the fact that, chemically, it is the primary source of soil nitrogen, and, physically, it gives to the soils many important properties that they would not otherwise possess and that are absolutely essential for large yields.

(A) EFFECT OF ORGANIC MATTER ON TILTH OF SOIL—GRANULATION.—Some soils are crumbly or mellow, and when plowed the furrow slice turns over loose and granular; while in others, especially silty or clayey soils, the plowed ground is likely to be cloddy, and heavy rain causes the soil to run together and bake when dry. The one is in good tilth while the other is not. If the crumbly soil is examined it will be found to be made up of crumbs or granules from the size of timothy seed to that of peas, formed by loosely cementing a number of soil particles or a number of smaller granules together. These crumbs vary in size in different soils, and even in the same soil at different seasons. This texture, or peculiar granular condition, is brought about by natural causes acting upon certain constituents of the soil and not by tillage, although tillage helps to bring about the condition sooner, as when cloddy ground is harrowed after a shower. The moisture develops a friable condition, and the use of the harrow simply hastens the work of nature. Without the shower it would have been almost impossible to get the ground into good shape.

This granulation or crumbly condition is a necessary property for silt and clay soils. If we take a handful of dust from the road we find that it looks and feels quite different from a handful of dry mellow soil from a well-managed field. The former is made up largely of incoherent soil particles, while the latter is made up of granules or crumbs of various sizes. Black clay loam, frequently called "gumbo," the soil commonly found in low, flat prairies in central Illinois, usually exhibits this property, while the brown silt loam of the rolling prairie shows it to a less extent. The heavy clay soils of the river bottoms sometimes go under the name of "buckshot" land, because of their granular character. This property of granulation gives to a soil some of the advantages of a sandy soil without its disadvantages, in that it makes it easier to work and keep in good tilth, while it retains moisture and plant food well. The size of these granules varies with the soil and the length of time of exposure to the elements. They are larger in spring than later in the season. The summer and fall rains frequently almost destroy them and it may require a winter's freezing and thawing to develop them again. It is generally recognized that the soil is in better condition for plowing after a cold winter, and this is undoubtedly due to the granular character developed by freezing. A cold winter may not be sufficient

to restore this condition after a very wet summer, as was seen in the spring of 1903 after the heavy rainfall of the summer of 1902 in central and northern Illinois. The fact was generally recognized that the soil was not in good physical condition even after a winter almost as cold as usual.

Mr. R. C. Lloyd, while a senior student in this University, made some interesting studies of the causes of granulation. He found that organic matter was one of the chief constituents concerned, and that moisture (alternate wetting and drying) and frost (alternate freezing and thawing) were the principal agencies in developing the property of granulation. Samples of the clay soil from the Mississippi River bottom in Illinois and the prairie brown silt loam from the University farm were used in his experiments. The effect of freezing and thawing upon the latter soil was studied in a ditch six feet deep and eighteen inches wide, left open during the winter. By spring it was three feet deep and forty inches wide, having been filled with the granules that were produced on the sides of the ditch by freezing and thawing. In studying this ditch it was found that the surface soil granulated much more readily, and that the granules were of a different shape from those formed from soil of lower depths, in that they were more angular, were harder to break apart, did not run together so readily when water was applied, and that when the granulated structure was destroyed it was again brought about by the action of water alone or of water and frost.

Plate I is a photograph of the ditch in the spring. Plate II is a photograph of the granules from different depths. Figures 1, 2, and 3, granules of surface, subsurface, and subsoil. Figures 4 and 5, large granules of subsoil. Figure 6, the smaller granules formed from the larger by freezing and thawing.

A sample of the bottom land clay was moistened, thoroughly worked, and molded into a ball. It was then frozen and thawed alternately, for six different times, when it was found to contain many broad, deep cracks. It was then moistened and dried alternately for three times, when the ball fell to pieces with granulation perfect.

Mr. Lloyd used the following experiment to show the effect of organic matter on granulation. Both soils were used in this experiment, and were thoroughly puddled to destroy any granules that might exist. A ball was made of each kind of soil after being puddled, but with no further treatment. Another set of balls was made from the soils after the soluble salts had been leached out with hydrochloric acid, and still another after part of the organic matter had been leached out by first leaching with a one percent solution of hydrochloric acid and then with dilute ammonia. After freezing and thawing twice, the balls were as shown in Plate III. Figure 1 is the ball of untreated brown silt loam, and Figure 6 the bottom land clay. Figure 3 is the brown silt loam



PLATE 1. DITCH IN SPRING.

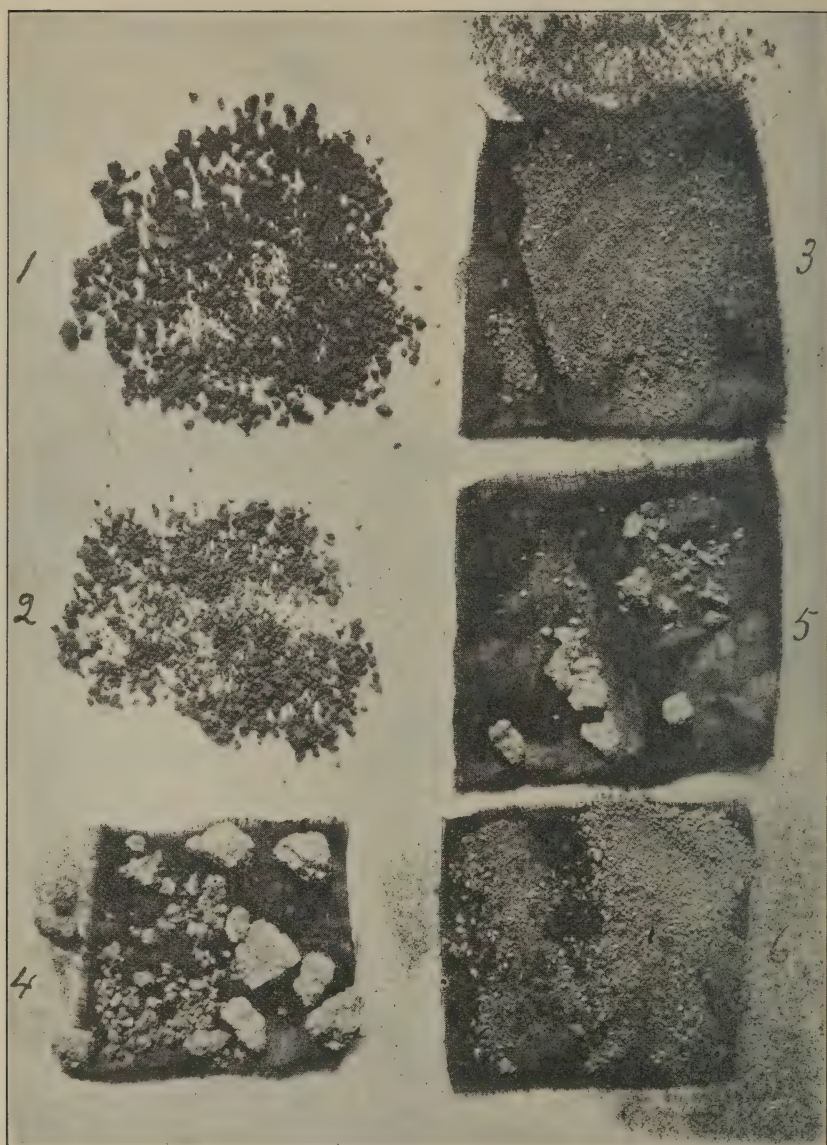


PLATE 2. GRANULES OF DIFFERENT SIZES.

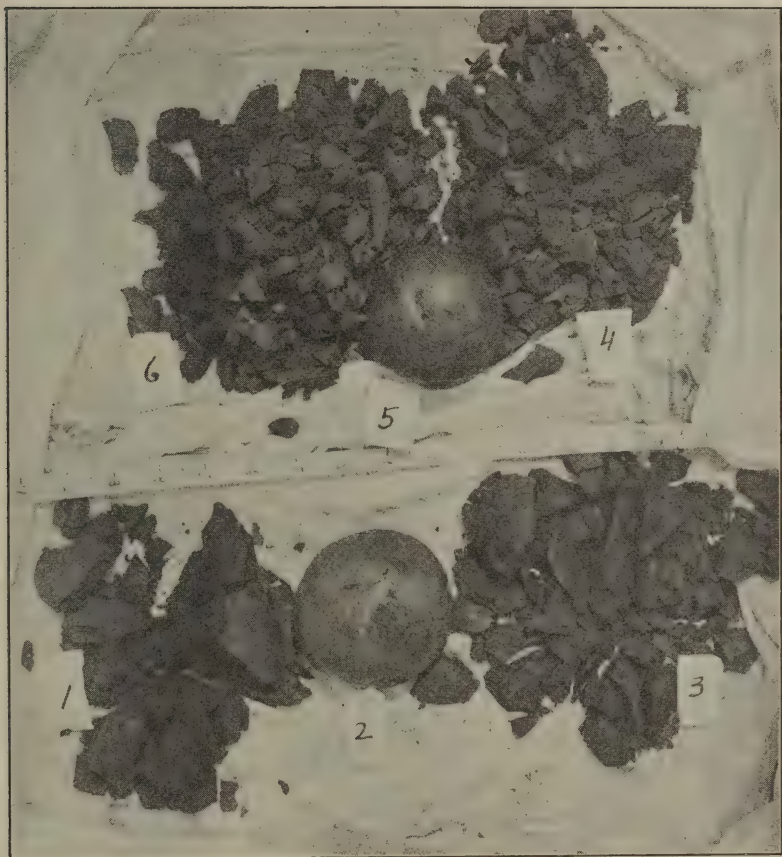


PLATE 3. EFFECT OF FREEZING AND THAWING ON THE SAME SOILS TREATED IN DIFFERENT WAYS. FIGS. 2 AND 5 WITH PART OF THE ORGANIC MATTER LEACHED OUT.



PLATE 4. EFFECT OF FREEZING AND THAWING ON THE SAME SOILS AS IN PLATE 3, BUT WITH THE ORGANIC MATTER RESTORED TO FIGS. 2 AND 5.

leached with acid, and Figure 4 the bottom land clay. Figure 5 is the brown silt loam leached with ammonia, and Figure 2 the bottom land clay. From Plate III it is seen that those balls from which the organic matter had been partially extracted were affected but little, while the others were broken up into granules. The organic matter that had been extracted was then thoroughly mixed with the soil from which it had been removed, and balls formed from this were frozen and thawed twice. They broke up into granules just as the untreated soil had done. Plate IV, Figures 3 and 6, show the silt loam and bottom land clay, respectively, that have had the organic matter replaced and been frozen twice. Figures 1, 2, 5, and 6 show where lime has been added with but little effect. From these experiments and from many field observations, it is evident that organic matter forms one of the most important constituents in producing the good tilth that it is necessary for good soils to possess.

(B) EFFECT OF ORGANIC MATTER ON MOISTURE CONTENT OF SOILS.—Every one knows how important it is to have a plentiful supply of moisture for the growing crop, but few realize the value of organic matter in maintaining the supply in time of drought. The organic matter acts as a sponge. Its effects upon moisture content are evident in two ways, (1) in the increased storage capacity and absorbent power for water, and (2) in preventing evaporation by its retentive power and by allowing a more perfect surface mulch than could otherwise be formed. Sand permits of rapid percolation with comparatively small amounts of water retained. If different amounts of organic matter are added to the sand, the quantity of water retained increases with the increase of organic matter. Table 1 shows the effect of this constituent upon the retention of water. Peat was used in the experiment, and this and the different mixtures of sand and peat were placed in tubes two inches in diameter and eighteen inches long. The same amount of water was then added to each. After percolation ceased, the amount of water retained by one hundred grams of the mixture is shown in the table.

TABLE 1.—EFFECT OF ORGANIC MATTER ON RETENTION OF MOISTURE.

	Grams of water retained by 100 grams of the mixture.
Coarse sand	13.3
Coarse sand with 5% peat.....	18.6
Coarse sand with 10% peat	24.7
Coarse sand with 20% peat	40.0
Peat	184.0

It will be seen from this that a few tons of manure per acre will appreciably affect the water-holding capacity of the soil. If eight tons were added, this would be equivalent to at least two tons of dry matter. Since manure is very similar to peat in its water-holding power, these

two tons will be capable of holding about four tons of water in the soil, or will increase the water capacity of the surface soil nearly five-tenths percent.

At one of the experiment fields in England two plots of similar soil had been growing wheat for twenty-five years. One had nothing added in the way of manures or fertilizers, while the other had an annual application of fourteen tons of farm manure per acre. After a long continued rain, the moisture content of the first was 29.9 percent, while in the second it was 60.2 percent, showing slightly more than 30 percent in favor of the field containing the larger amount of organic matter.

Evaporation takes place quite rapidly from the surface of compact soils where the particles are in close contact with each other. The moisture moves as a thin film around the soil particles, but can only move when these particles are in contact. If this chain of soil particles is broken at any place movement of water in that direction must cease. A compact soil furnishes a great number of these continuous chains by which the moisture passes to the surface, where it is evaporated. If the soil is stirred or loosened in any way, very many of these lines are broken, a less amount of water moves to the surface, and as a result evaporation is retarded.

The water, then, can be best retained in the soil by maintaining a loose layer on the surface, thus breaking capillary movement. Cultivation is necessary in order to do this, but it is much easier to maintain this mulch in some soils than in others. It is not difficult to maintain a mulch in sandy soils, but in silty and clayey soils it is more difficult. Every beating rain destroys the granules, compacts the surface, and, unless the soil is in good tilth, the mulch must be renewed at the very first opportunity to prevent excessive loss of moisture. A large amount of organic matter in a soil tends to keep it loose and granular, and a mulch may be kept with less difficulty in such a soil than in soils with less organic matter.

(C) EFFECT OF ORGANIC MATTER ON "RUNNING TOGETHER" OF SOILS.—The complaint is often made that soils "run together" and bake after every heavy rain. This is often true of fine-grained silty or clayey soils, but not of sandy ones. It is due to the breaking up of the soil granules into their individual particles by the beating of the rain drops, and this produces a puddled condition of the surface which, when dry, forms a hard crust through which the young plants can pass or force their way only with great difficulty. The crust being somewhat impervious to air, the growth of the crop may be hindered by lack of aeration. The roots of growing plants require oxygen, as do also the bacteria of the soil that carry on the process of nitrification, producing nitrates for plant growth. A crust on the surface when corn is young soon causes it to become yellow, indicating a lack of nitrogen, probably due to the

fact that nitrifying bacteria are unable to carry on their work properly for want of oxygen. A crust also causes a loss of moisture by increasing evaporation, the soil having been so compacted by the rain that the soil particles have been brought into close contact with each other and continuous capillary connection has been established, so that the water now may pass rapidly to the surface, where it is evaporated.

"Running together" may be largely prevented by increasing the amount of organic matter. This cements the soil particles together into granules, holding them so firmly that only the hardest rains break them down, and furnish the puddled condition necessary for the formation of a crust. Every one has seen the effect of an old strawstack or manure heap on the soil. Places where these have been are always mellow when cultivated, because of the organic matter contained in them. Every soil should contain enough organic matter so that it will not "run together" except with the heaviest rains, and even then not so as to interfere seriously with the ordinary physical phenomena of the soil.

(D) EFFECT OF ORGANIC MATTER ON WASHING OF SOILS.—Wherever land is not level and the rainfall is greater than can be absorbed, more or less washing occurs. The amount depends upon the physical composition and texture of the soil, the extent and slope of the surface, the presence or absence of vegetation, and the character and amount of the rainfall.

A very gravelly or sandy soil that allows the water to pass downward readily is not likely to wash badly, for the reason that very little water runs off by surface drainage even on a considerable slope. If, however, the soil is a silty or clayey one, it will absorb water very slowly, and a large amount will run off and carry with it the best soil. The water naturally seeks the lowest places and the large volume of water is sufficient to do a great deal of washing, and soon deep gullies will be formed that will render the land worthless for ordinary agricultural purposes.

When soils are likely to wash, an ounce of prevention is worth many pounds of cure. The best remedy is a preventive one. This applies especially to the formation of gullies on hillsides, by which a farm may be completely ruined in a very few years. When these ditches are small they may be filled with rubbish that will check the current of water and cause the sediment to be deposited there, which will result in the filling of the ditch. The general washing that takes place from the surface of all hilly and even slightly rolling land should be looked after as well. This washing removes the best soil and lowers the productive capacity of very large areas of land in Illinois. Much of this was not of the best to begin with, and the removal of the thin top soil has rendered many tracts almost worthless. Silt and clay soils are much more liable to wash than sandy ones, because the particles are smaller, consequently more easily carried by water; and, as these soils do not absorb the rainfall

readily, because the pores are small, so there is more water to run off. While it is impossible to change the inorganic constituents of soils to any appreciable extent, yet they may be treated in such a way as to change the texture in a few years. This may be done by incorporating organic matter in them. The partially decayed material cements the soil particles into granules or grains, giving it somewhat the porosity and looseness of a sandy soil. The granules thus formed are too large to be carried readily. When in this condition, water will be absorbed rapidly, and if deep plowing is practiced, the ground will be in condition to absorb a heavy rainfall. It is estimated that ten inches of loose soil will absorb two inches of rainfall. A large supply of organic matter should be maintained, if possible, by growing legumes and cover crops. In fact a soil that is liable to wash badly should never pass through the winter without a cover crop. The roots will hold the soil particles together, and the top will prevent rapid surface currents from forming.

(E) EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS.—It is a well-known principle that dark surfaces absorb the sun's heat, while white surfaces reflect it. Our choice of clothing, dark in winter and light in summer, is an application of this principle. As a general rule the more organic matter a soil contains the darker it is, and this makes it a poor reflector of heat, but a good absorber of it. Consequently, dark or black soils become warmer than those of the same physical composition but lighter in color. Experiments have been tried in which the surface of a soil has been blackened with soot and the same soil whitened with lime. During the day the blackened soil was from 2° to 5° warmer than the whitened soil at a depth of six inches. A similar experiment has been tried by the writer, the soil used being a light-colored gray silt loam. On the surface of one lot of soil about one-fourth inch of black loam was scattered so as to cover completely the light colored soil. The same conditions as to moisture were maintained. Thermometers were placed in each soil so that the bulbs were one, two, and four inches beneath the surface, with the results as given in Table 2.

TABLE 2.—EFFECT OF COLOR OF SOIL ON TEMPERATURE.

	LIGHT.	DARK.	LIGHT.	DARK.	LIGHT.	DARK.
Time.	1 inch below surface.	1 inch below surface.	2 inches below surface.	2 inches below surface.	4 inches below surface.	4 inches below surface.
11 A. M.	78° F.	82° F.	74° F.	75° F.	69° F.	70.5° F.
12 M.	81	86.5	77.5	81	73	75.5
1 P. M.	83	91	80	86	76.5	81
2 P. M.	85	92	81.5	88	78.5	84
3 P. M.	86	91	82	88	80	86
4 P. M.	85	89	82	88	81	87
5 P. M.	81.5	85	81	86	81	86

By comparing the above figures it will be seen that the dark colored soil is much warmer than the other, the greatest difference being eight degrees for one inch below the surface and six degrees for two and four inches. This difference in temperature noticeably affects the germination and growth of plants. The difference between times of germination on light and dark soils is a matter of common observation. In spring when corn begins to come up the rows may be seen sooner upon the low, black soil than upon the higher, lighter colored soils, provided the conditions of moisture are about the same for each. This is usually attributed to the fact that the black soil is the richer, but the amount of plant food in the soil has very little to do with the growth of corn up to the time when it may be seen in rows. It will reach this stage in pure sand devoid of any plant food. Careful experiments which we have carried on under controlled conditions have clearly demonstrated that germination is more rapid in dark soils than in light colored soils.

That organic matter plays a more important part as a soil constituent than is generally supposed is evident. It is clearly apparent that many do not fully realize the value to the soil of maintaining the supply of this essential constituent. A "run down" farm in Illinois is frequently land that has been cropped till a large part of its organic matter has been destroyed, leaving the soil in a very poor physical condition. Sometimes this is the only difficulty, although usually soils deficient in organic matter are also found to be poor in nitrogen and in phosphorus. The only remedy for the physical condition is to furnish the soil with the needed organic matter, thus bringing back the condition of good tilth that is absolutely necessary for properly carrying on the physical processes. It is a deplorable fact that large amounts of vegetation, such as straw and corn stalks, are burned every year upon land that is in sore need of organic matter. In the wheat region of the southern part of the state burning straw is quite common in some sections, and thus the land is deprived of a large amount of organic matter that could be turned back to the soil with considerable profit. In central Illinois corn stalks are considered a necessary evil, and the easiest way to get rid of them is thought to be the best; but we forget that when stalks are burned we are destroying one of the most valuable constituents of our soils. The only excuse that can be offered for burning stalks or stubble is to kill insects that are injurious to some of our crops. With this object in view, the burning of such materials may sometimes be justifiable.

Farm manure furnishes only a limited amount of organic matter when we consider the amount of land that needs it. One of the largest sources of this constituent should be the growing of green manures—rye, buckwheat, rape, and legumes, such as clovers, cowpeas, or soy beans. The clovers are especially useful, being biennial or perennial plants and nitrogen gatherers. The roots penetrate deeply into the subsoil, thus promoting aeration and percolation, besides bringing plant food to the surface and taking a supply of nitrogen from the air.

APPENDIX.

LINES OF SOIL WORK.

A thorough knowledge of soils can be obtained only by studying them along two lines, chemical and physical. The chemical study of soils has to do with the amount and availability of the different elements of fertility contained in them, the kinds and quantities of plant food required by different plants, and the methods of maintaining or increasing the supply of these plant food elements in the soil. The physical comprises a study of physical or mechanical composition, of texture and its improvement, of moisture and its movement, of temperature and its control, of aeration, and of soil management. The physical side of soils is included under Soil Physics.

ORIGIN OF SOIL MATERIAL.

Soils are made up of small particles of different kinds of minerals mixed with more or less organic matter. These small mineral particles were originally formed by the breaking down of rocks through the agencies of weathering and decomposition. These include a variety of forces that do their work under different conditions but all produce the same ultimate effect, that of changing solid rock into fine material that may become the home of plants.

One of the most common physical agents is that of temperature, which does its work in two ways: (1) by the freezing of water contained in rocks and (2) by changes in temperature producing an increase or decrease in volume.

All rocks contain more or less water, and when this water freezes it expands and exerts enormous pressure—about one ton to the square inch. This would be sufficient to shatter most rocks if frozen when the pore space was completely filled. As it is, the expanding water or ice breaks many rocks into pieces, and weakens others so that repeated freezing is enabled to accomplish what a single freeze could not do. These small pieces are acted upon in the same way until they are reduced to material that will form soil.

It is common knowledge that a substance expands when heated and contracts when cooled. This change of temperature and consequent increase or decrease in volume takes place on the surface most readily, and the strain thus produced in rocks is sometimes sufficient to cause pieces to scale off, and even when this does not occur the rock is weakened so that other forces may do more effective work.

When a sufficient amount of this fine material is formed for the growth

of plants, especially shrubs and trees, the roots penetrate the crevices in rocks and by their growth pry off fragments, which are broken down by other agencies.

All rocks have more or less water passing through them, however slowly it may be. This water frequently dissolves out the more soluble material, which is often the substance that cements the crystals or particles of the rock together. This leaves it very loosely cemented, and other agencies soon reduce it to sand or other smaller particles. Rocks are made up of a number of minerals such as quartz, mica, feldspar, calcite, etc. Water containing oxygen and some other substances may have the power of decomposing or changing these minerals into other minerals. These may be more bulky than the first and tend to rupture the rock, or they may be softer and will be acted upon more rapidly by atmospheric agencies.

In some or all of these different ways rocks are broken down into particles of various sizes. These do not always remain where they are formed, but may be transported by wind or water and in their movement help to wear down solid rock or grind stones, gravel, or sand into still finer material. The wind aids in soil forming by driving the sand against hard surfaces, gradually wearing them away. The wind is also a distributing agent for soil material, picking up the fine dust and carrying it for some distance. In this way soils have been formed over large areas and others have been modified over still larger areas. Even in our state it is believed that much of the soil known as loess has been largely if not entirely formed by the action of wind.

Running water is also a very important agent in the formation and distribution of soil material. During heavy showers more or less water runs off the surface and coarse or fine particles are moved, depending upon the volume and velocity of the moving water. Even on comparatively level areas some movement of soil material takes place, but it is in the ravines, gullies, and streams that the greatest amount of work is done by this agent. The volume and velocity of the water in many streams is sufficient to move all sizes of material, even to boulders weighing tons, and the crushing and grinding that goes on during the movement of these boulders, gravel, and sand is enormous. The finely ground-up material as well as that washed in by streams is carried by the larger creeks and rivers and finally deposited, forming flood plains along their courses, or deltas at their mouths.

Glaciers have also been exceedingly important agents in the formation and distribution of soil material. While they are usually confined to arctic or mountainous regions, yet in times past, glaciers in the form of moving ice sheets hundreds of feet thick came down from the north, covering nearly all of the United States north of the Ohio and east of the Missouri Rivers, extending as far south as the Ozark Ridge in our

own state, and covering all the rest of Illinois except the northwest corner and possibly a small area in Calhoun county. As this ice sheet advanced from the north, it picked up, pushed and carried along with it rocks of all sizes, shapes, and kinds. These, ground and crushed against each other and upon the surface over which they passed, formed immense amounts of fine material, which, together with the sand, gravel, and stones, was deposited when the ice melted. If the front edge of the ice sheet melted as rapidly as the glacier advanced the material was deposited as a ridge where the edge melted, and after the glacier had disappeared this ridge marked the terminus or limit of the glacier. These ridges or moraines, are familiar objects in our state. The soil material formed by glaciers is a mixture from all kinds of rocks. It furnishes some of our best soils.

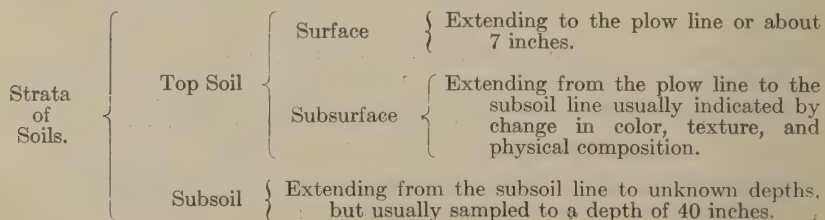
By means of the agencies briefly referred to above, the land has been covered with a layer of material of varying thickness but extending to bedrock, the upper part of which we designate as soil. In some places this layer is hundreds of feet thick, while in others the solid rock is still exposed. In such places either sufficient time has not elapsed for the agencies to form a soil since the present conditions came about, or the soil material has been removed by wind and water.

THE STRATA OF THE SOILS.

Most soils have two natural divisions as to depth, the top soil and the subsoil.

The top soil varies in depth with the soil type, usually being from six inches to twenty inches deep. It is frequently a little coarser in physical composition than the subsoil, because the finest particles are carried away by running water, and, furthermore, as water percolates downward through this soil, these finer particles have a tendency to move down with it, and some fine material is thus carried down into the subsoil. The color of the top soil varies with the type, but depends largely upon the amount of organic matter or iron or both. The organic matter is the more common, and gives to soils a black or brown color. Iron compounds usually give a reddish brown color very much like iron-rust.

The top soil is very properly divided into the surface soil and the subsurface soil, as indicated in the diagram:



The surface soil extends as deep as the ground is plowed, which is usually not more than seven inches. This is the soil that the farmer knows most about, and it is this that he can and does change in composition most readily by adding vegetable material, manures, and fertilizers. This is the part that requires most careful management, as it is the most important part of the soil in development of plant food, in germination of seeds, and in growth of crops, since it is largely concerned in absorption and retention of moisture, aeration, and temperature. It is commonly the darker part of the soil, because of its larger organic matter content.

The subsurface soil lies between the surface soil and the subsoil, or between the plow line and the subsoil line, where the change of physical composition, texture, or color indicates the beginning of the subsoil. This change varies in depth with the soil type, but in most Illinois soils it is from 16 to 18 inches from the surface of the ground, thus making the subsurface layer about 9 to 11 inches thick. In physical composition it differs but little from the surface soil except that it contains somewhat less organic matter, this constituent diminishing with depth. The color of the subsurface soil is often very similar to that of the surface. It varies with the type, but depends primarily upon the amount of organic matter and iron present. There are some places where the top soil is only 6 or 8 inches deep, and rests directly upon the subsoil. In such cases there is no subsurface stratum, as the plow line and subsoil line coincide.

The subsoil extends usually from 18 or 20 inches to unknown depths. It is commonly sampled for analysis to a depth of 40 inches, or one meter. The color is usually yellow, and the subsoil is frequently spoken of as "clay," although it commonly contains much more silt than clay. The physical composition of the subsoil is frequently different from the top soil in that it contains more of the finer soil particles that have been carried downwards from the soil above by percolating water. It generally contains only a small amount of organic matter. The character of the subsoil is of very great importance, for upon that, to a large degree, depends the drought-resisting power of the soil. If the subsoil is coarse sand or gravel the water will pass through it and cannot be drawn back by capillarity and so is lost to the crop, which will suffer from drought in consequence. If, however, the subsoil is silty or clayey, a large amount of water will be retained in it and much of what passes to lower depths will be brought up within reach of the roots by capillarity. Subsoils sometimes contain a layer of impervious material such as compact clay, carbonate of lime, or oxide of iron, which is commonly called hardpan. This is very objectionable if within three feet of the surface, since it prevents the upward and downward movement of water and the deep penetration of plant roots. The crops on level hardpan land suffer from

much rain because the water cannot get down through this to drain away, and they suffer from drought because the water below this layer cannot be brought up through it by capillarity. A semi-impervious hardpan is quite common in the southern part of this state, north of the Ozark Ridge. This hardpan is compact silty clay containing iron. It can probably be greatly improved by tile drainage and a liberal use of deep-rooting crops, such as red clover.

CONSTITUENTS OF SOILS.

Soil Constituents.	{	Inorganic Matter	{	Clay	.001 mm.* and less.
				Silt	.001 mm. to .03 mm.
				Sand	.03 mm. to 1 mm.
				Gravel	1 mm. to 32 mm.
				Stones	32 mm. and over.
				{	Organic Matter

*25 millimeters equal 1 inch.

INORGANIC MATTER.

The constituents of soils include two general classes, (1) inorganic and (2) organic. The inorganic form the basis of soils and are named not with reference to chemical composition, but according to the size of the individual particles. These comprise the following five classes of material: (1) clay, (2) silt, (3) sand, (4) gravel, and (5) stones. (See diagram.) These, as explained above, are the product of broken-down rocks.

(1.) Clay—The smallest particles found in soils, those less than .001 millimeter, or 1-25000 of an inch in diameter, go under the name of clay. These extremely small particles are chiefly kaolin, the hydrated silicate of aluminum formed largely from the weathering and alteration of feldspars. Clay possesses certain properties that are characteristic, as shrinkage upon drying, plasticity, puddling, and granulation.

Shrinkage of soils containing considerable clay is well shown in certain low or flat lands. During dry weather cracks form in the ground a foot or two in depth and sometimes even an inch or more in width at the top. The presence of organic matter is responsible for part of the shrinkage. By the formation of these cracks the roots of plants are broken and avenues opened for greater evaporation. As these cracks are caused by the drying out of the soil, the maintenance of a good mulch will prevent excessive cracking. The amount of shrinkage of clay and clay mixed with different proportions of sand has been determined by experiment. Bricks were made from moistened soil and measured before and after drying.

Table 3 gives the results of this experiment.

TABLE 3.—SHOWING SHRINKAGE OF CLAY AND CLAY WITH SAND.

	Percent of shrinkage.	Amount of shrinkage in a linear foot.
Clay soil	13.8	1.65 inches
Clay soil with 10% sand	13.4	1.60 inches
Clay soil with 20% sand	12.1	1.45 inches
Clay soil with 50% sand	9.2	1.10 inches

One of the first steps in the manufacture of any wares from clay is the thorough working or kneading of the clay so as to break down any granules that exist into their ultimate particles. This is called puddling the clay. This will enable the clay worker to make fine-grained, close-textured wares, impervious to air and water. Puddling clay soils is just the thing that should be avoided in the management of soils of this class. Plowing or working when too wet is likely to destroy the granules and thus puddle the soil. It is then impervious to water and will bake very hard when it becomes dry and thus become unfavorable to the growth of crops. It is difficult to restore the granular condition, but this may be developed by the action of frost although it may require several years to completely restore it.

Clay is plastic; that is, it can be molded into different shapes and pressed into thin leaves and will retain these shapes when dried. Its plasticity depends upon its tenacity. This tenacity renders it much more difficult to plow than sandy soils. The particles tend to hang together and were it not for the property of granulation (see page 3), it would be almost impossible to cultivate such soils. Although clay soils when dry are the lightest with the exception of the peaty soils, when equal volumes are compared, yet they are called "heavy" soils from the difficulty in working them. (See weight of soils p. 21.)

Clay never forms the entire soil as there is always more or less silt and even fine sand mixed with it, that was deposited by the same agency that formed the soil. When well drained, a clay soil is usually one of our best although it will not dry out so quickly after a rain or warm up so rapidly in spring as a sandy one. It retains moisture well, so well in fact that it is apt to be considered a cold, wet soil; but it can only be so called when not well drained. Although not so common as silt soils, yet clay loams and clay soils are frequently found in the bottom lands of the larger streams of the state and in the low, poorly drained areas of the Upper and Middle Illinoisan and Wisconsin Glaciations (see Circular 64). These soils may readily be distinguished by their plasticity, their tenacity or stickiness when wet, and their "gumbo" character. In many localities the word "gumbo" is applied to them. They possess one very important property—that of granulation.

(2.) Silt—The grade of particles next coarser than clay is called silt and this is perhaps the most abundant soil constituent. It very

frequently goes under the name of clay, especially when lacking in organic matter. The particles are very small, ranging from .001 to .03 millimeter, or from 1-25000 to 3-2500 of an inch in diameter. Pure silt is not sticky or plastic like clay (but the individual particles are too small to be seen with the naked eye or to be distinguished by feeling with the fingers). Silt forms a very large part of the sediment of muddy streams. Silty soils are very common and it is probably true that at least two-thirds of the soils of the state are silty soils or soils in which the larger part of the constituents is silt, although there is always more or less clay and sand present. From the nature of the origin of soil material the constituents would necessarily be mixed to a certain extent, but wind and water acting upon these, later, would sort them in favorable localities so that almost pure clay, silt, or sand soils would be formed. The brown, rolling prairie soils of central and northern Illinois and the gray soil of southern Illinois are good examples of silty soils. These soils require a little more care in management than light or sandy soils. The particles are small and tend to form compact soils which are "heavier" to work than sandy ones. In silty soils there is a tendency for the particles to run together and bake after heavy rains, especially if deficient in organic matter. When in good tilth they are easy to cultivate, retain moisture well, are easily drained, and form some of the world's most productive soils.

(3.) Sand—Sand is very properly divided into coarse, medium, and fine, the size ranging from .03 millimeter or about 1-750 of an inch to 1 millimeter or 1-25 inch. The individual grains even of fine sand can be distinguished by most people with the naked eye or by rubbing between the fingers. Sand may be composed of several minerals, chief among which are quartz, feldspar, mica, and iron oxides. Quartz is by far the most common, probably forming more than nine-tenths of the sand of our soils. Sand alone does not usually contain an abundance of plant food because of the leaching effect of water, but the soil is so porous that roots will reach out much farther than in more compact soils. When liberal applications of farm manure are made good crops of corn or vegetables may be grown. If considerable amounts of the finer soil constituents are mixed with the sand, together with organic matter, an excellent soil results. The sand present in such a soil destroys to a large extent the tenacity or tendency to stick together, which the finer constituents possess. Those who work such soils recognize the fact that they work more easily than those made up of silt and clay, and hence the term "light" soil is applied to them. These soils are usually heavy when we take weight into account. If we take a cubic foot of sand soil when dry and compare its weight with the same bulk of a dry silt or clay soil, it will be found that the sandy soil actually weighs more than the other. The following table will show the differences in weight. Three hundred cubic centimeters of each were used without compacting.

TABLE 4.—SHOWING COMPARATIVE WEIGHT OF SOILS CONTAINING DIFFERENT AMOUNTS OF SAND.

Soil.	Approximate amount of sand in soil, %.	Weight in grams.
Sand	100	500
Loamy sand	86	476
Sandy loam	75	426
Loam	55	402
Silt loam	40	362
Clay	10	325

Sandy soils warm up early in the spring making them very desirable for early truck crops, as in market gardening. Evaporation from the surface of a soil tends to keep it cool. In sandy soils the water passes down and is carried away by drainage, comparatively small amounts being lost by evaporation. The sun's heat that is required to evaporate the moisture from a finer grained soil is used in sandy soils for raising the temperature. Differences of from one to two weeks in maturity of crops frequently are noticeable between a very sandy soil and a clay or silt soil.

(4.) Gravel—This includes particles from 1 millimeter or 1-25 of an inch to 32 millimeters or about $1\frac{1}{4}$ inches in diameter. Gravel when alone is worthless as a soil because of the fact that water passes through it very readily, leaching out the plant food and leaving the soil destitute, or at least very deficient in both nourishment and moisture. When the finer constituents are present, some gravel makes the soil more porous and consequently more easily drained, aerated, and worked; and it is not a very undesirable constituent unless too coarse, and present in too large quantities.

(5.) Stones—When the rocks are broken down, many of the more resisting fragments remain, and when these are more than 32 millimeters ($1\frac{1}{4}$ inches) in diameter, the term stone is applied to them. There is only a small amount of stony soil in the state and while it is inferior in some respects, yet it is not worthless. Its value, however, depends upon the amount of the other constituents present, the slope of the surface, and the size of the stones. Even a large number of stones does not necessarily render the soil worthless, especially if there is considerable fine sand, silt, or clay to give it retentive power for plant food and moisture.

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THE SWINE INDUSTRY FROM THE
MARKET STANDPOINT.

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INTRODUCTION.

The producer of swine very often, on account of his lack of knowledge of market conditions, does not realize the maximum value for his product. In view of this, an attempt is made to bring before the people a few market considerations which will help the farmer to a better realization of market conditions, and thereby put him in position more intelligently to produce and market his annual hog crop.

MARKET.

1. "A hog market is a place where hogs are regularly bought and sold."

2. By "market" is also meant "The state of trade as determined by prices, supply, and demand." If conditions are such that there is a good demand for hogs, there is an "active" or "good market." If the conditions are reversed, so that there is a poor demand for hogs, there is a "dull" or "poor market." These meanings of the terms "good market" and "poor market" must not be confused with "high market" and "low market." It is possible to have a "poor high market" and a "good low market," and vice versa; e. g., hogs may be selling for \$7.00 per cwt. and there may be a poor demand for hogs at this price and the supply on hand may be great. This would force down the price. In such a case we would have a "poor market" from the market standpoint, but at the same time it would be a "high market" or "good market" from the farmers' standpoint. The reverse may be true when hogs are selling at \$3.00 per cwt. Thus it is seen that the terms "good market" and "poor

market" may have opposite meanings when considered from the market standpoint and from the farmers' standpoint.

The demand for pork by people who do not produce it is the principal factor that goes to make a hog market. This, however, is not constant, for the ability of the consumer to buy meat must not be forgotten. Meat is the most expensive part of the bill of fare, consequently it will suffer most during a period of financial depression. That is, there will at such times be less demand for pork, consequently for hogs. During a period of prosperity the reverse is true, and pork is in greater demand. As an illustration of the effect this fluctuation in the demand for pork has on the number of hogs in the United States, there may be cited the following:

In 1892 there were in the United States 52,000,000 hogs, in 1899, 38,000,000, and in 1901, 57,000,000. The decrease of 14,000,000 hogs from 1892 to 1899 must be attributed to the financial depression which was responsible for a smaller demand for pork and for hogs, forcing the price down to where hogs could not be produced at a profit, consequently fewer were produced. This was augmented by the comparatively large number of hogs in the country in 1892. From 1899 to 1901 the number increased from 38,000,000 to 57,000,000. Here the increase of 19,000,000 hogs must be attributed to the increase in price, which, in turn was caused by the prosperity of the country enabling the people to buy more meat. This was hastened by the small number of hogs in the country at the close of the period of "hard times."

In connection herewith it might be well to notice that high price of hogs and large numbers of hogs do not always go hand in hand. In 1901 there were in the United States 57,000,000 hogs, and in 1903 only 47,000,000. Here there was a decrease of 10,000,000 hogs, while at the same time the price went up from \$6.00 per cwt. in 1901 to \$7.78 per cwt. in 1903. A possible explanation for this may be that in 1901 the hog-raising industry had been developed to its utmost capacity. The price for live hogs at this time was very high—so high, in fact, that a great many of the brood sows were sold by the farmers, who feared that the price might drop to an unprofitable basis before another crop of pigs could be matured. Moreover, hogs were constantly being sold at a younger age and during this period of high prices farmers sold out their stock as closely as possible. Then again, the price of corn was high, and high-priced corn and a small number of hogs usually go together.

In the swine-growing industry high prices stimulate production up to the point where prices are very high and the probability of a lower market seems evident. After this they retard production, as the farmer will sell his surplus stock and a large number of his brood sows as well, causing a large decrease in the hog stock of the country. The market may be kept at a high level either by normal or abnormal conditions while

the number of hogs is decreasing. Such were the conditions during the latter part of the period from 1901 to 1903.

The supply of hogs is further regulated to a slight extent by the prevalence of disease. When hogs are healthy and thriving, the number increases, but when disease is prevalent the number decreases. Then again, hogs are so prolific, and a person can start with so little capital, that this line of animal industry is subject to much shifting. Large numbers of people go into the business of growing hogs, forcing the price down and then going out, thus causing the price to go up.

The demands on a great central market like Chicago for hogs and for hog products vary greatly with the different places from which the demands come, e. g., Cambridge and Boston demand a hog weighing from 220 to 280 pounds, and use it principally for cured meats. Baltimore and Pittsburg use a hog weighing about 200 pounds, and New York uses one that weighs from 130 to 180 pounds. These are used principally for the fresh-meat trade. Detroit uses mixed hogs weighing from 170 to 250 pounds for both fresh and cured meats. Buffalo has developed a demand for pigs that weigh from 50 to 130 pounds. These different places get into the habit of using cuts of meats of certain sizes and thus create a demand for hogs of the different weights. Since hogs are shipped to all these eastern places from the West, and since the demands of these various places are so different, they can all be supplied. This very fact helps to establish a great market such as Chicago, where hogs of all descriptions can readily be bought and sold. Besides this, there is also a foreign demand, which varies with different places, as, e. g., "bacon" for London made from light, lean hogs, and "clear backs" for French trade, made from prime heavy fat hogs.

Pork packing in smaller towns by local slaughterers is carried on much more extensively than the slaughter of cattle in similar institutions. This can easily be done, because a hog-killing establishment can be constructed at a comparatively small cost, and the by-products in this business are not so valuable as is the case with cattle. What the local packer loses in waste of offal he more than regains in the saving of freight. He can buy his hogs locally and sell the meat locally. Besides the large and small packing houses, there are establishments of all sizes, according to their location and other conditions, such as shipping and selling facilities.

LOCATION OF PRINCIPAL MARKETS.

Markets naturally are located in places that are best suited for the purpose—places where the largest number of hogs can be bought at the lowest prices, and where the means of distributing the output of the packing houses are the best. The two factors are not of equal weight. The dressed carcass can be transported with less expense than can the live

animal; therefore the principal markets are located in proximity to the country where most hogs are produced. This is in the corn belt. The following are the principal hog-raising states, with the round number of hogs produced annually: Iowa, 7,000,000; Illinois, 4,000,000; Missouri, 3,000,000; Indiana, 3,000,000; Nebraska, 3,000,000; Ohio, 3,000,000; Texas, 2,000,000; Wisconsin, 2,000,000, and Kansas, 2,000,000.

The principal hog markets in the United States, with the approximate number of hogs slaughtered annually, are as follows: Chicago, 7,000,000; Kansas City, 4,000,000; Omaha, 2,000,000; St. Joseph, 2,000,000; St. Louis, 2,000,000; Indianapolis, 1,000,000; Buffalo, 1,000,000; Sioux City, 1,000,000; and Cleveland, 500,000. New York takes about 500,000, and Boston 1,500,000 annually, but these can hardly be considered markets from the farmers' standpoint, as this supply is principally bought in other markets and shipped to these places. This takes some of the hogs shipped from the western markets of the United States. In the above figures, only the hogs that are slaughtered are taken into consideration, not those that are shipped out alive. Chicago annually ships out one million live hogs, making the total handled at that place annually about eight million.

INFLUENCE OF RETAILER ON MARKET.

The influence of the pork retailer on the hog market is indirect, but nevertheless is of considerable magnitude. He has more of a uniform price on his article from week to week and from month to month than is found on the live hog. He has his retail price based on a certain standard price for live hogs, and will not change this with small fluctuations in the price of hogs when between given limits. When the price of hogs goes above this limit he immediately raises the price of pork, and it is logical and necessary that he should do so. But when the market price for hogs has reached the upper limit and begins to recede, the retailer is slow to follow this by a reduction in the price of pork. This is the time when he can apparently make up for the inevitable losses with least appearance of intruding upon the rights of the consumer. But by holding the price of meats at a high level the consumer is forced to purchase a smaller quantity, thus lessening consumption. This affects the hog market very materially by reducing the price of live hogs; while at the same time it does not permit the retailer to fill his coffers materially more than he otherwise would, for the higher the price of pork, the less is the consumption, and the lower the price of pork, the more is the consumption. He would make just as much profit on a large volume of business with a small margin as on a small volume of business with a large margin; besides, his large business would be of exceedingly great benefit to the hog grower, because the greater demand for meats would check the downward tendency in the prices of hogs and bring them to

a standstill at a higher level. It is clear, then, that if the retailer would follow the market on a decline as promptly as he does on a rise, he would not be damaging himself and would be of great benefit to the hog grower.

CHANGES OF MARKET DEMAND WITH SEASON.

The relative demand for light and heavy hogs in great central markets like Chicago varies with different seasons of the year. Generally speaking, heavy hogs are at a premium in winter, when light hogs are most numerous, and in the summer, when heavy hogs are plentiful, light hogs are in greater demand.

It would seem at first thought that the market always demands what the producer cannot supply. But there is a reason for this apparent discrepancy between relative supply and demand of light and heavy hogs. The demands of the markets in general are more constant than would at first thought appear to the casual observer. The fluctuation in price from heavy to light and from light to heavy hogs is caused, to a great extent, by the supply of hogs on the market. The reason that light hogs are in less demand in winter at the great central markets is that at this season of the year many of the outlets for pork from this class of hogs are closed on account of home production. A great deal of this goes to Europe, the South, the East, and back to the farmers in the country. During the winter months much of this supply is furnished by home product. That is, Europe, the East, and the South raise some hogs of their own, and these are usually slaughtered in the fall or early winter and consumed during the winter. The farmer who supplies the hogs for the great markets will very often slaughter the animals for home consumption in winter, but in summer he has neither the time to do this work, nor has he the necessary appliances for curing and preserving his meat, consequently he can purchase it on the market with greater economy. Thus it can easily be seen that from all these sources there is a greater demand at the markets for pork from light hogs during the summer than during the winter months. On the other hand, heavy hogs are in greater demand during the winter, because this is the packing season. That is, it is the season when such meats as mess pork, short cut mess pork, dry salt sides, rough sides, short clear sides, short rib sides, bellies, and clear bellies are prepared—such as can be stored for a considerable length of time without spoiling. Considering these conditions, it is evident that there should be a greater demand for heavy hogs in winter and for light hogs in summer. Owing to the inability of the country to supply at the proper season just what the market demands, there must necessarily be considerable fluctuation in prices, and also in weight for the various classes, e. g., if heavy hogs are wanted and light hogs are furnished, the latter will naturally sell at a discount,

and the line of limitation in weight will be shifted downward so as to allow some of the heavier hogs of the light-hog class to sell in the heavy-hog class. The reverse is also true.

SUPPLY OF HOGS ON A MARKET.

The supply of the different kinds of hogs on a market changes with the season. Most pigs are farrowed in the spring. By the time winter sets in many of them are ready to go to market in a finished condition and many more are sent in an unfinished condition for various reasons, such as lack of feed, lack of room, lack of thriftiness, and the need of money to meet pressing obligations. The result is that light hogs and pigs are forced upon the market in undue proportion during the fall and winter. How is it with the heavy hog? Pigs that were farrowed in the spring have not as yet had time to develop into heavy hogs, and fall pigs of the previous year which have not already been sold are not numerous enough to fill this gap. This causes a scarcity of heavy hogs in the late fall and early winter. In summer the conditions are reversed, giving more heavy hogs and fewer light hogs. The hog that is sent to market in the summer usually is one that was farrowed in the spring or in the fall of the preceding year and has developed into a heavy hog. Light hogs are scarce at this time because most of the pigs are farrowed in the spring. These factors usually work together to make a narrow range in prices between heavy and light hogs during the summer months and a wider range during the winter months.

This variation in the supply of hogs from the normal demand also has a tendency to lower prices. If the hogs on the market of a certain class are not sufficient to supply the demand for that class of hogs, this demand must necessarily be filled by hogs of another class. These will not command the price that they would if they were sold within their own class, provided the different classes sell on the same level, nor will they bring as much as the hogs whose places they are to take would sell for. It lowers the price because the supply of hogs furnished is of a different character than is demanded by the trade. This has a depressing influence on the market, and the total receipts for hogs sold partly outside their classes are less than they would be if sold entirely within their classes.

SELLING HOGS ON MARKET.

Hogs are usually sold on the open market by commission men. Any person can sell his own stock at the yards, but not being so well acquainted with the market, the yards, and the buyers, he cannot work to the same advantage as can a commission man.

When hogs are shipped, they are as a rule consigned to some commission firm. As soon as the stock is loaded at the shipping point, it is taken in charge by the railroad company, who forward a report to the

point of destination, thus informing the market center approximately as to the number of cars to expect the following day. When a car of hogs arrives at the yards in Chicago, it is taken in charge by the Union Stock Yards and Transit Company, which unloads the car, counting out the animals, making note of the dead and crippled ones, provided there are any, and delivering the stock to the commission firm to which it is consigned. After feeding and watering, the stock is sold to the highest bidder, not by auction, but by private sale. Each commission firm has its own section in the yards, which is conceded to it by common consent, the firm paying nothing for the privilege of doing business at the yards. The Yards Company charges eight cents per head yardage and seventy-five cents per bushel for corn fed to the hogs, which must be paid by the consignor of the stock. This, together with the terminal switching charge, pays for the use of the yards. The commission firm charges \$6.00 per car, or in smaller lots up to thirty head, ten cents per head for selling the animals. This charge as well as the freight, must also be paid by the consignor. Before the hogs go over the scales they pass under the eye of a government inspector, for which ten cents per car is charged. As soon as the hogs have passed over the scales, they go into the hands of the packer, the shipper, or the speculator. If to the packer, they go to the slaughter house, if to the shipper, they are reloaded and shipped, usually to the East; and if to the speculator, they simply go to another part of the yards, to be sorted and resold.

HANDLING AND SHIPPING HOGS.

To discuss the topic fully would take us too far from the market side of this subject, but there are a few distinctly market features to it that will bear discussion from that point of view. To sell to the best advantage, either in carload lots on the open market or in small droves to the country shipper, or to the local packer, hogs should be made to appear as well as possible. They should be well bred, so as to be of good form and all of the same color. They should be of the same size, consequently should have been farrowed as nearly as possible at the same time, and should show as much thrift, quality, and finish as possible. It is a well-known fact that shippers as well as killers make the smallest margin of profit on the best grade of stock handled. There is more difference between the best and medium grades of swine, as well as of other stock, on foot than there is between the carcasses of the same animals. A few white hogs in a drove may by their presence detract as much from the value of the drove as they individually are worth. In a drove of mixed colors, differences in size are much more apparent than in a drove of one color. If there is a small white hog in a drove of black hogs, he will surely be noticed, but if there is a small black one in the same drove he may be overlooked.

Hogs should be shipped so as to reach the market in the morning in time to be watered and fed before the best part of the market is over. This varies with prevailing conditions, but is between 7:00 and 11:00 a. m. In order to have them at their best on the market, hogs should not be over-fed, and should not have laxative feed nor salt before shipping. Neither should they have too much water. It is better to give them a moderate ration of dry feed before shipping, and give them some ear corn in the car. The car should be well bedded with wheat or rye straw in winter and should be bedded with sand in summer. Wheat and rye straw are better than oat straw for bedding in a car in which hogs are to be shipped, as the hogs will not perspire so much, causing them to become wet and steaming, which detracts much from their appearance. Sand in summer is cooler than straw. When arriving at market the hogs should be dry, lively, and not too gaunt.

SUMMARY.

1. The terms "good market" and "poor market" may have opposite meanings when used from the buyer's and from the producer's standpoint.

2. The fluctuation in the number of hogs in the United States is subject largely to the fluctuations in the financial condition of the country.

3. A high market price for hogs stimulates production up to the point where prices are very high and the probability of a lower market seems evident, then it retards production.

4. The demand for pork and for live hogs from different places varies between the widest extremes within the limits of the market classification, and this helps to establish a great central market for all classes and grades of swine.

5. Such a market is located where large numbers of hogs are produced, where transportation facilities are good, and where the business can be carried on cheaply and economically.

6. Chicago is the leading hog market of the world.

7. The retailer of meats has considerable influence on the hog market. By holding the retail prices of pork at a high level when the hog market is on the downward trend, he prevents increase in consumption, which, instead of checking, accelerates the downward tendency of the hog market.

8. The relative demand for light and heavy hogs changes with the season, heavy hogs being in greater demand in the winter and light hogs in the summer months.

9. Owing to the time required to develop a hog, and to the fact that most pigs are farrowed in the spring, the supply of hogs is not in harmony with the demand. Light hogs are the most plentiful in the fall and winter, and heavy hogs during the summer. This is contrary to the demand, and has a depressing influence on the market.





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